

Advanced Network Infrastructure for Distributed Learning and Collaborative Research

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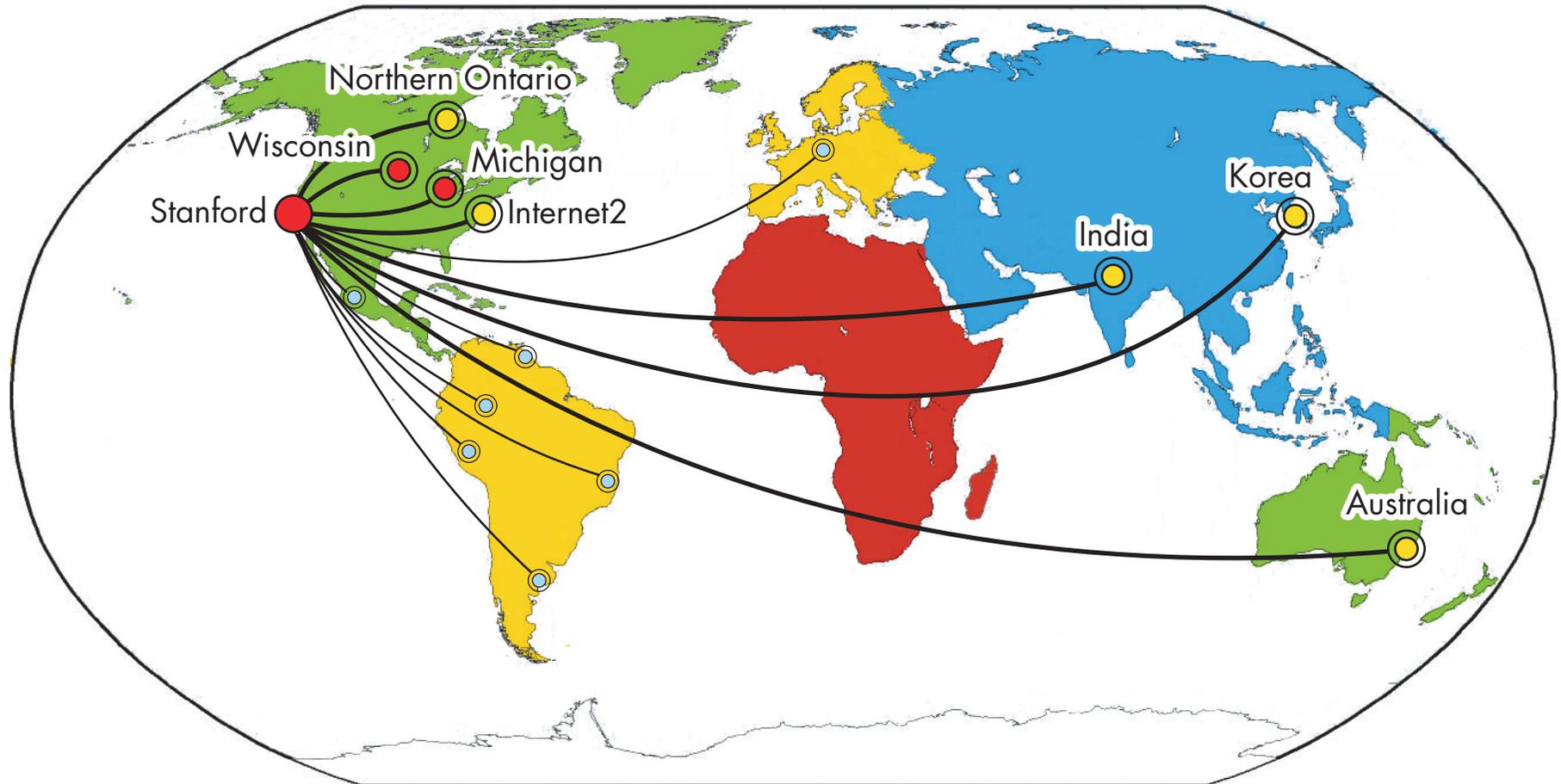
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University of Michigan, Ann Arbor

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September 30, 2003 – September 29, 2007



A Collaboration

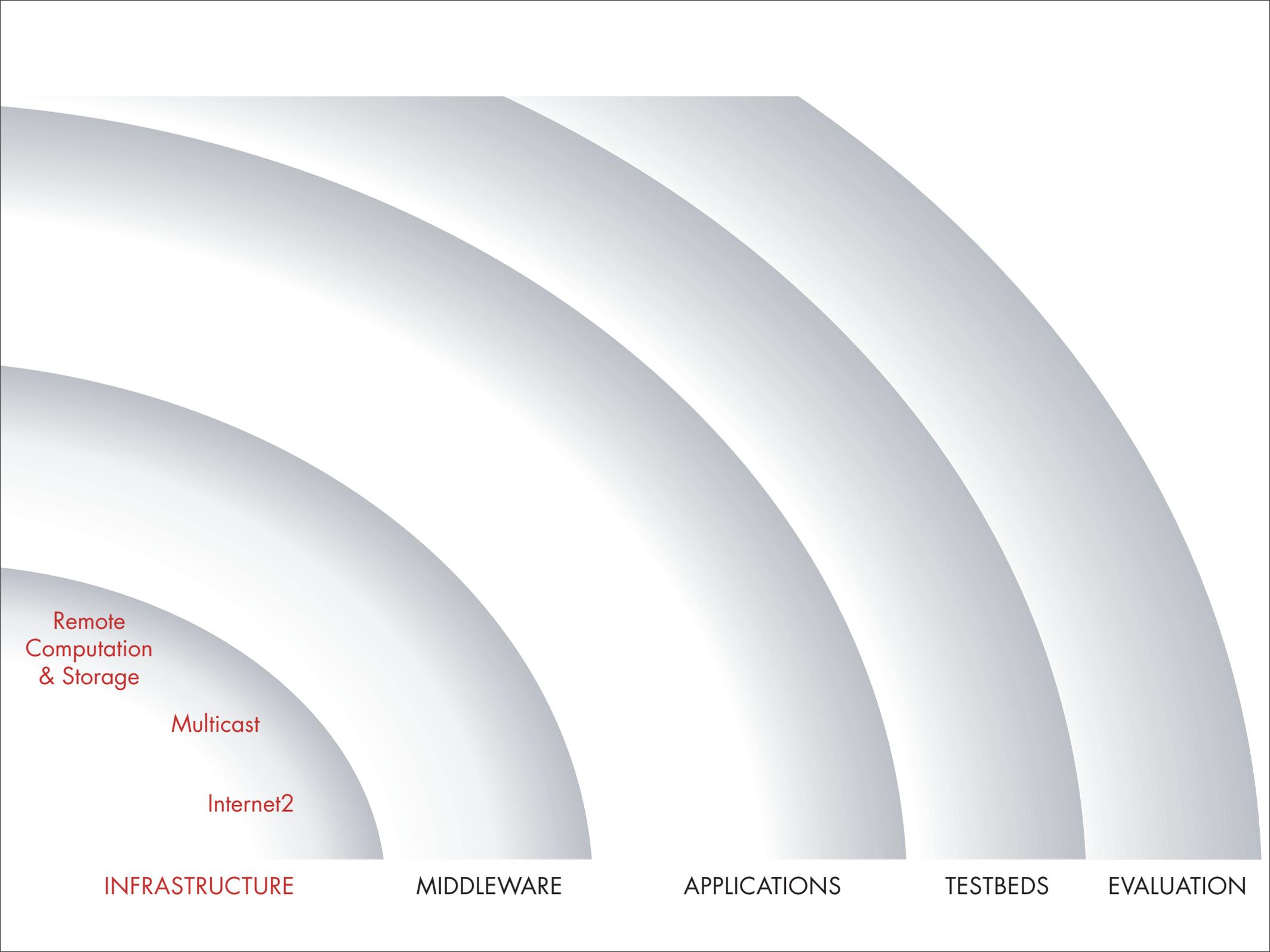


- A collaboration for Haptic Audio Visual Network for Education and Training (HAVnet)

NLM: Advanced Network Infrastructure in Health and Disaster Management

- Scalable, network aware, real-time technology applications
 - Application of these technologies in health care, medical decision-making, public health, large-scale health emergencies, health education, and biomedical, clinical and health services research
 - Testbed networks linking:
 - hospitals, clinics, health practitioners' offices, patients' homes, health professional schools, medical libraries, universities, medical research centers and laboratories, or public health authorities





Remote
Computation
& Storage

Multicast

Internet2

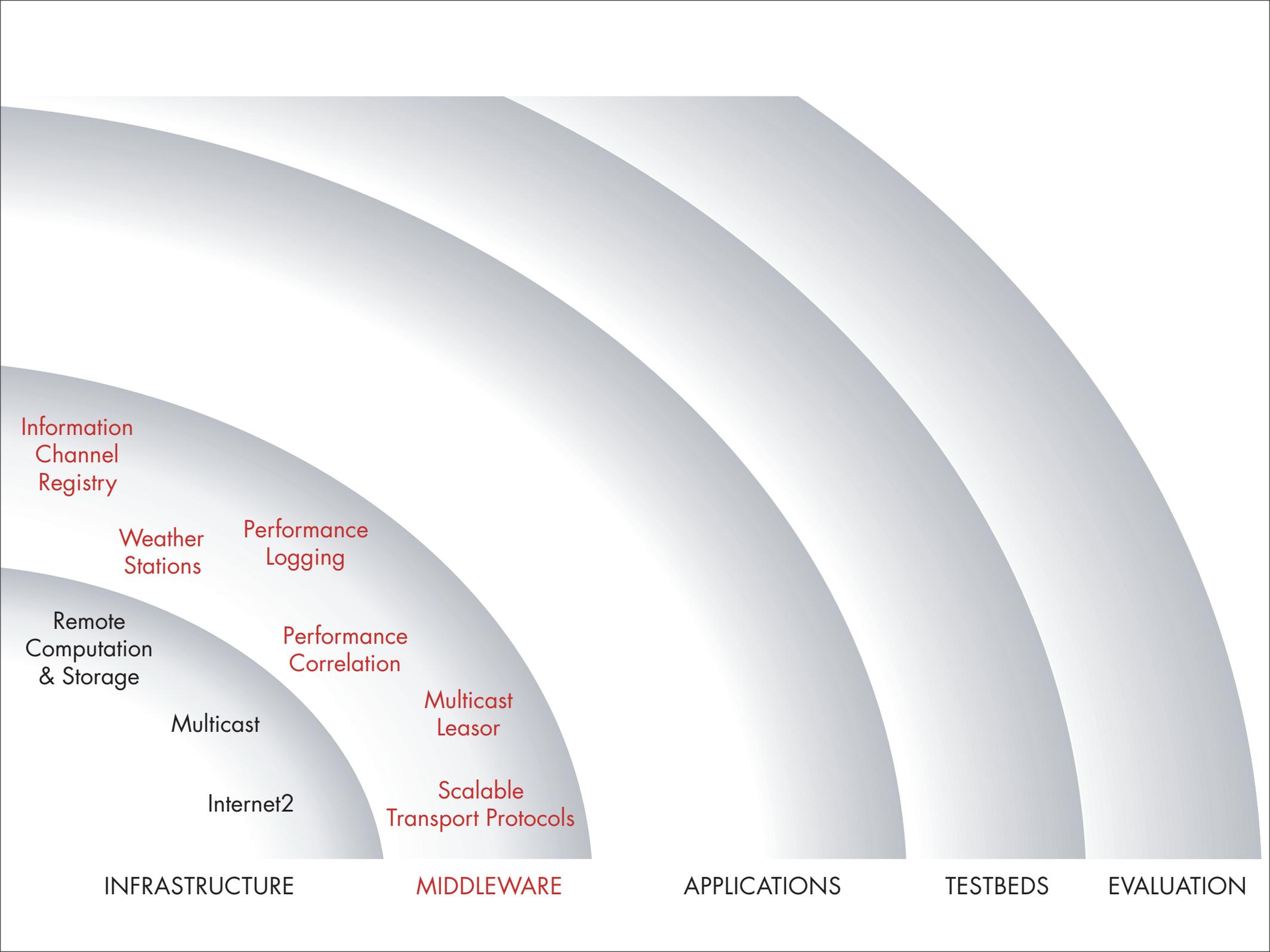
INFRASTRUCTURE

MIDDLEWARE

APPLICATIONS

TESTBEDS

EVALUATION



Information
Channel
Registry

Weather
Stations

Performance
Logging

Remote
Computation
& Storage

Performance
Correlation

Multicast

Multicast
Leasor

Internet2

Scalable
Transport Protocols

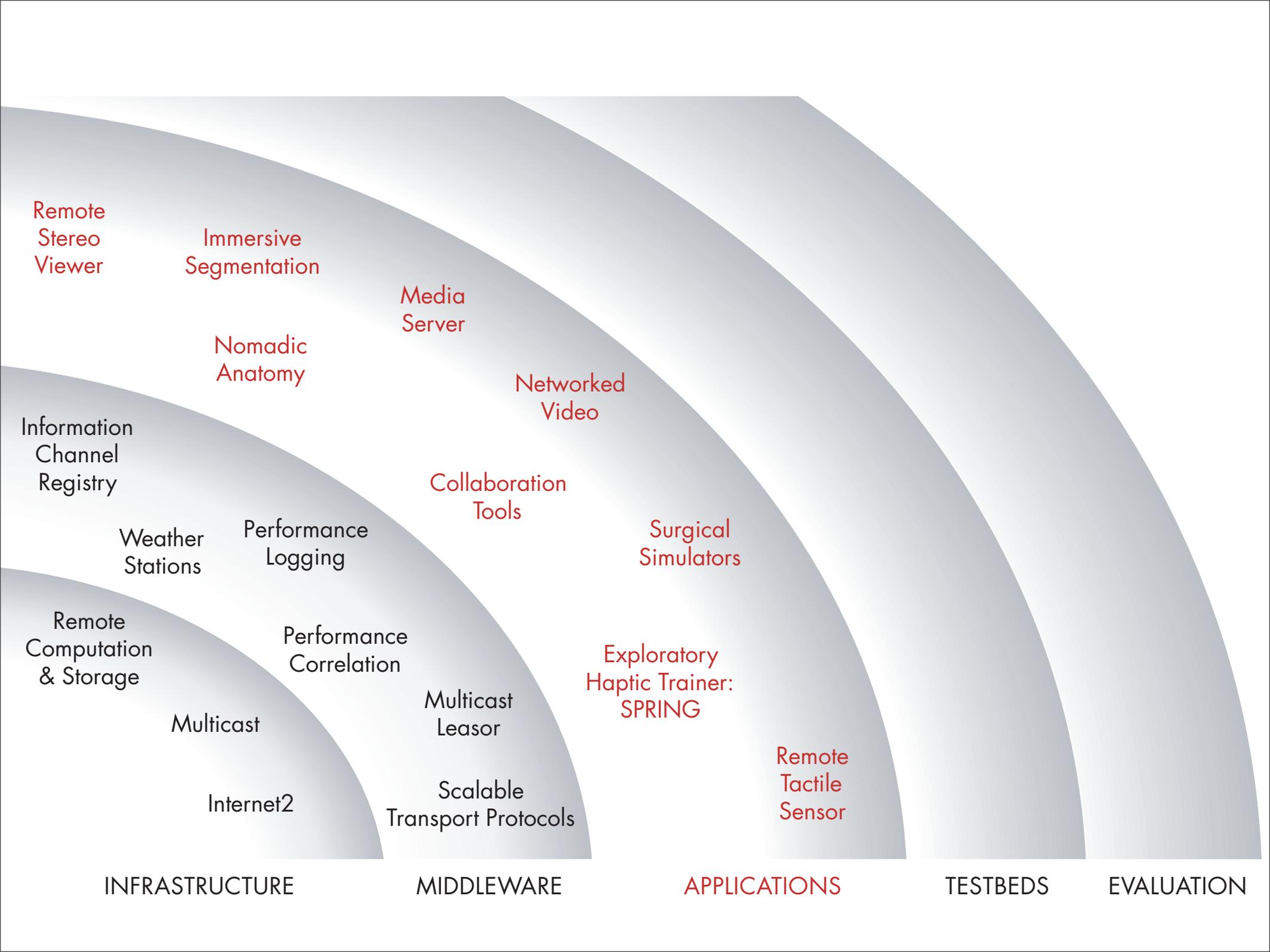
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Remote Stereo Viewer

Immersive Segmentation

Media Server

Nomadic Anatomy

Networked Video

Information Channel Registry

Collaboration Tools

Weather Stations

Performance Logging

Surgical Simulators

Remote Computation & Storage

Performance Correlation

Exploratory Haptic Trainer: SPRING

Multicast

Multicast Leasor

Remote Tactile Sensor

Internet2

Scalable Transport Protocols

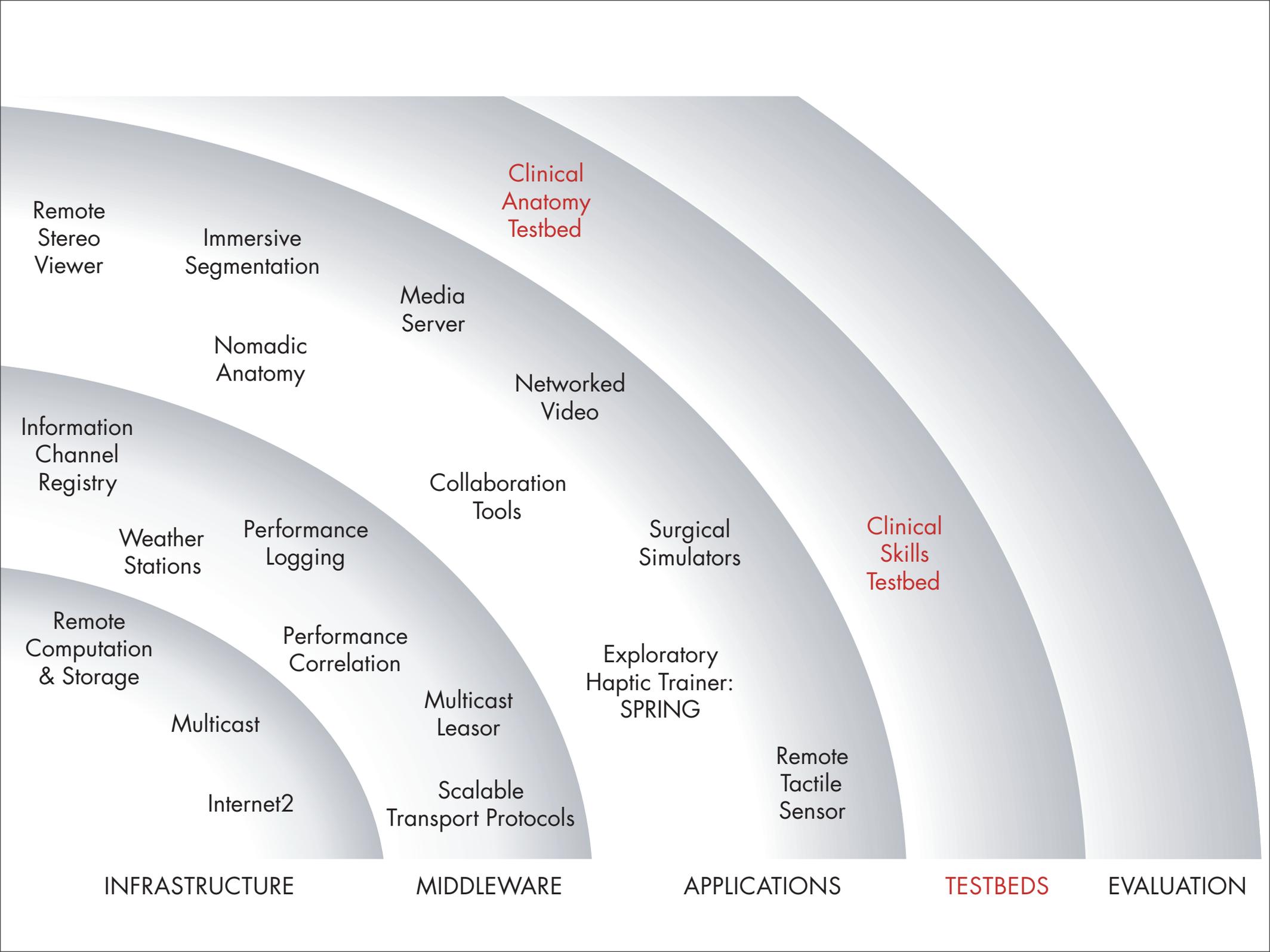
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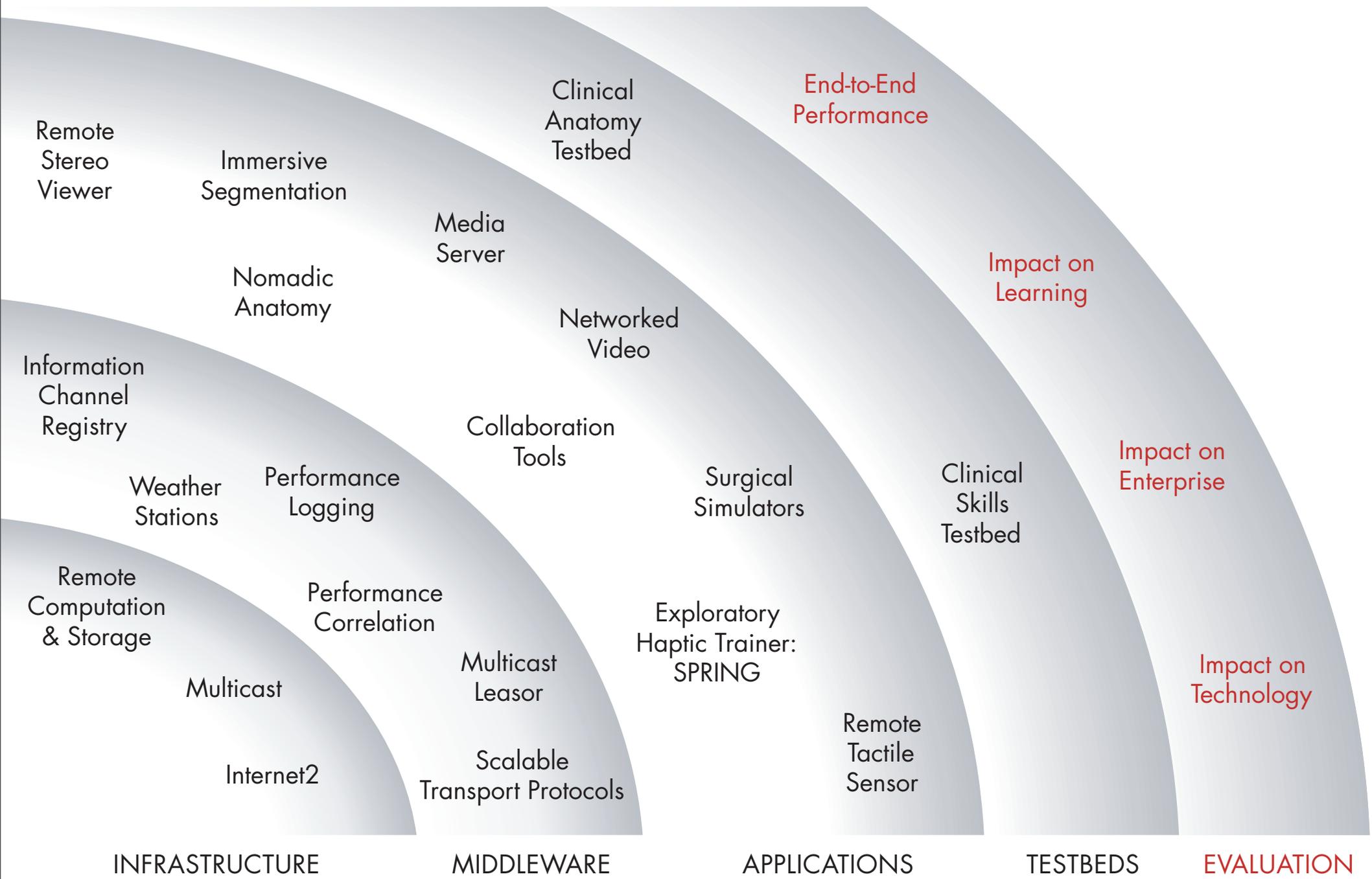
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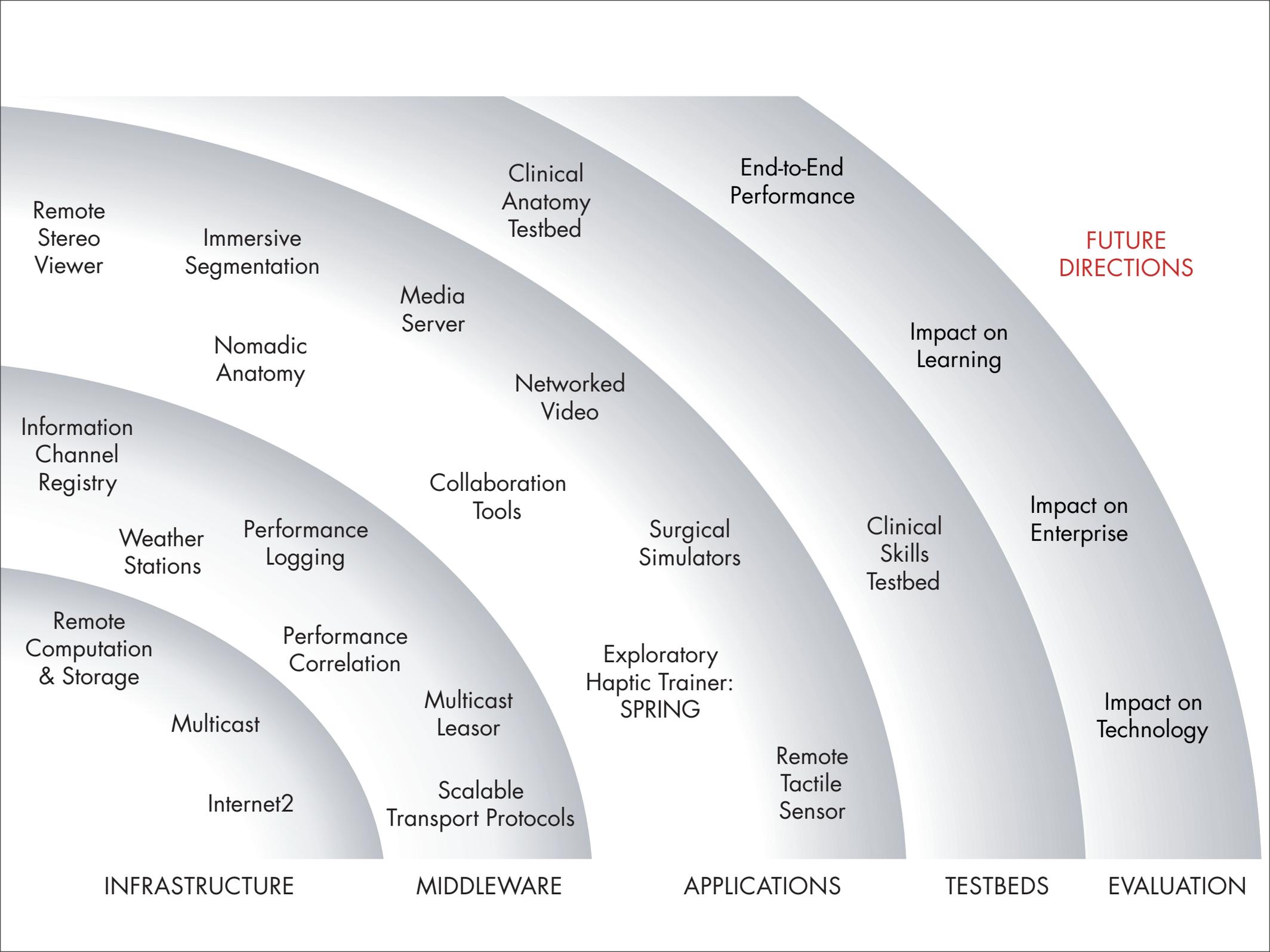
INFRASTRUCTURE

MIDDLEWARE

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EVALUATION



Remote Stereo Viewer

Immersive Segmentation

Clinical Anatomy Testbed

End-to-End Performance

FUTURE DIRECTIONS

Nomadic Anatomy

Media Server

Impact on Learning

Information Channel Registry

Networked Video

Collaboration Tools

Impact on Enterprise

Weather Stations

Performance Logging

Surgical Simulators

Clinical Skills Testbed

Remote Computation & Storage

Performance Correlation

Exploratory Haptic Trainer: SPRING

Impact on Technology

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INFRASTRUCTURE

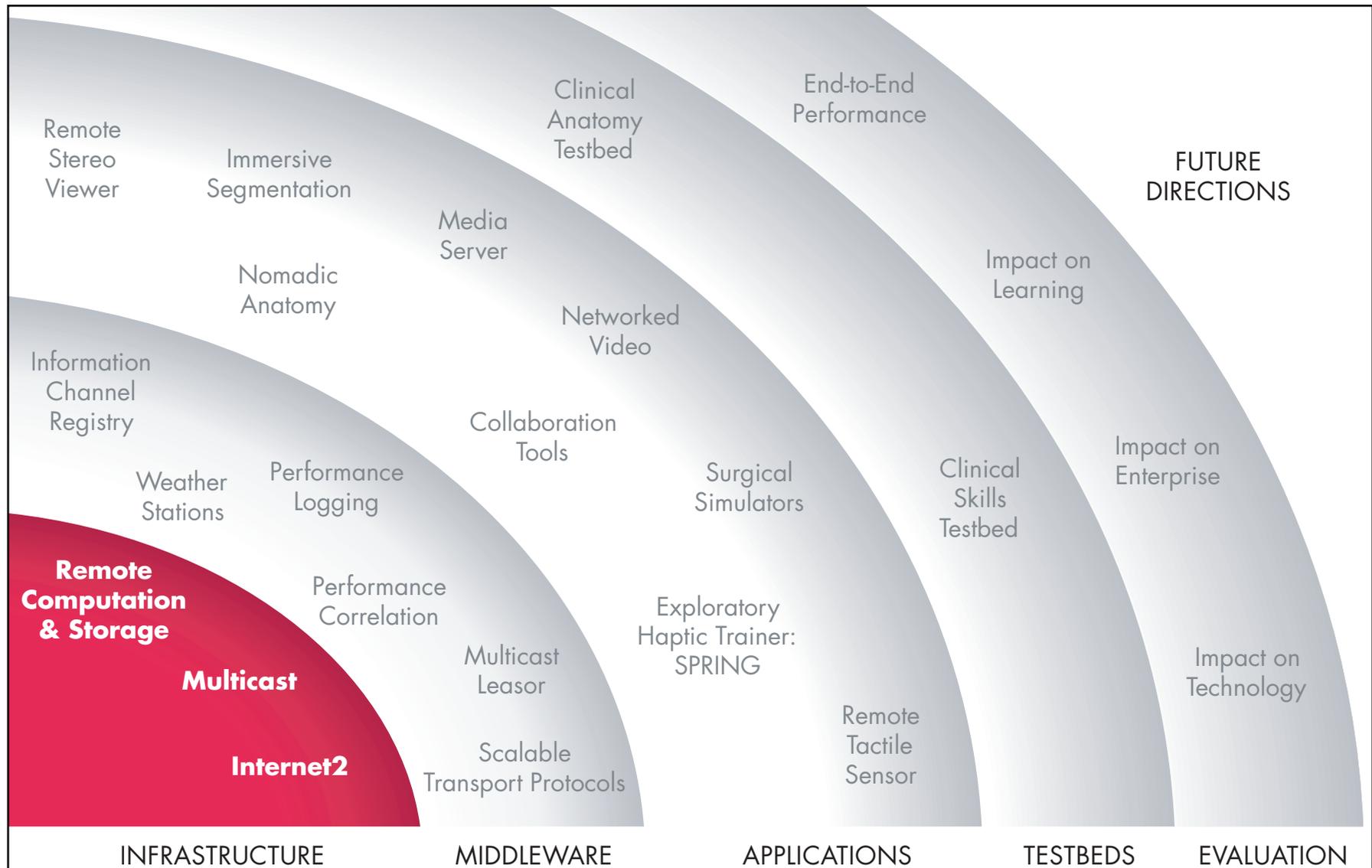
MIDDLEWARE

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TESTBEDS

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Infrastructure

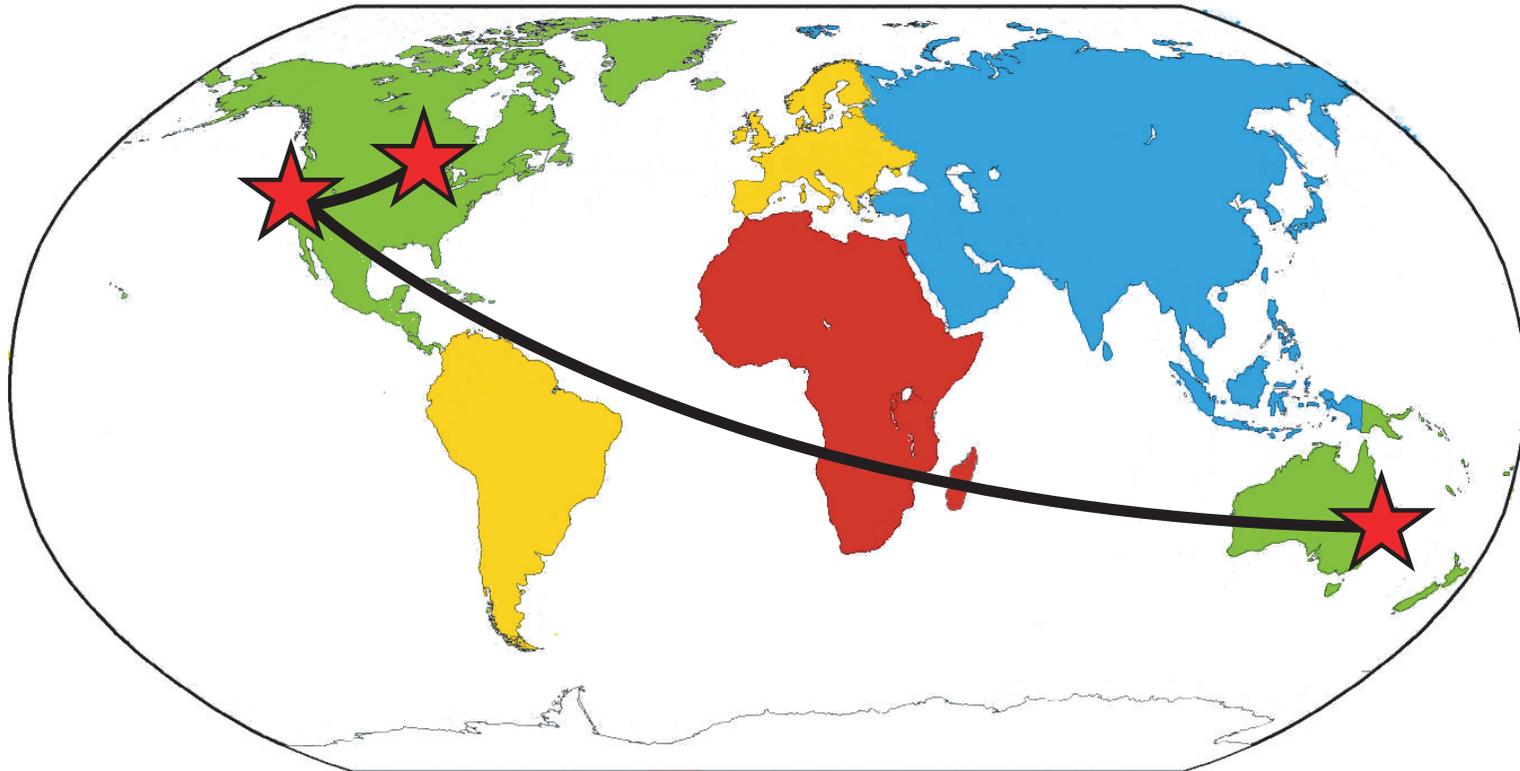


Infrastructure: Network Characteristics

Remote
Computation
& Storage

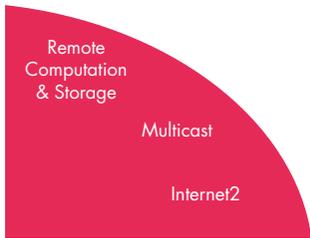
Multicast

Internet2



- Local: within Stanford
 - National: Stanford – Wisconsin
 - International: Stanford – Australia

Measuring Network Traffic



Stanford – Wisconsin:
1 Gbps, 16 hops

Within Stanford:
1 Gbps, 2 hops

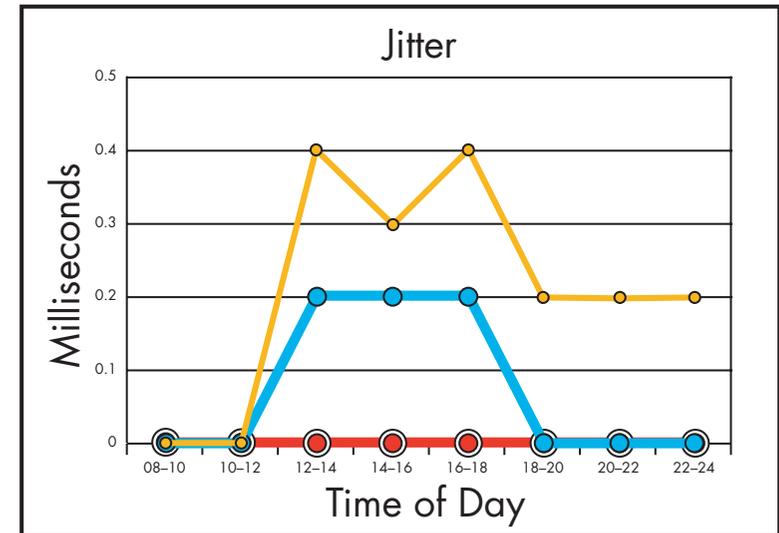
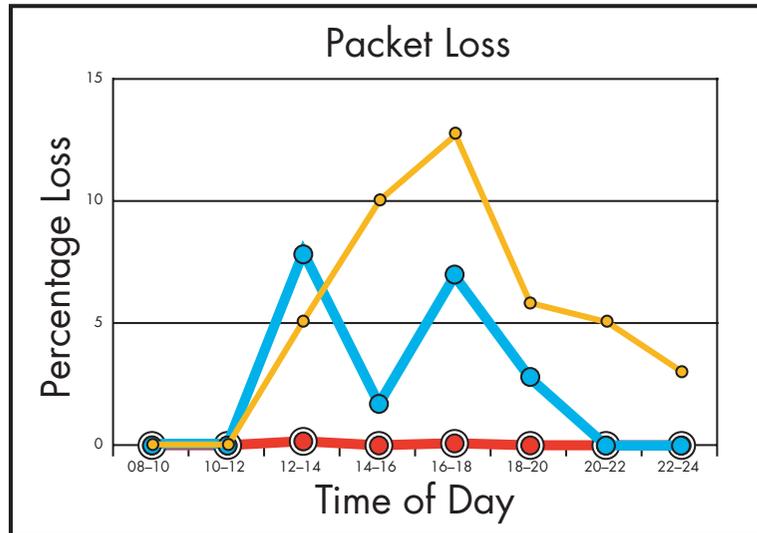
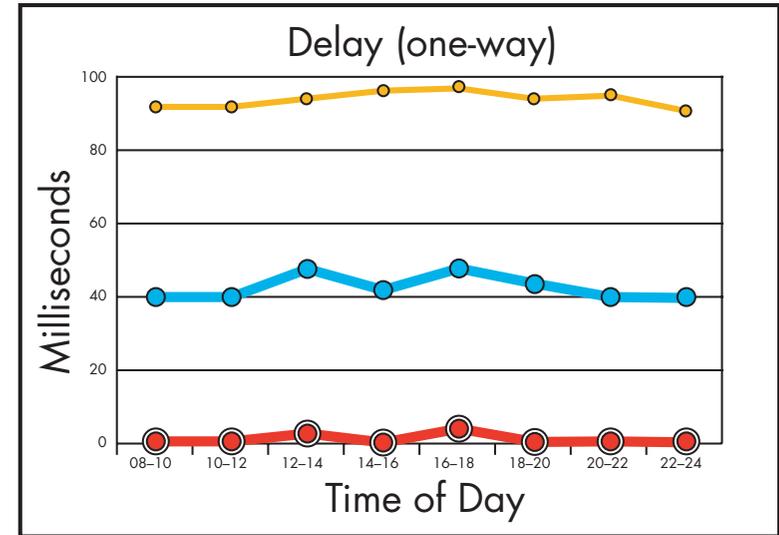
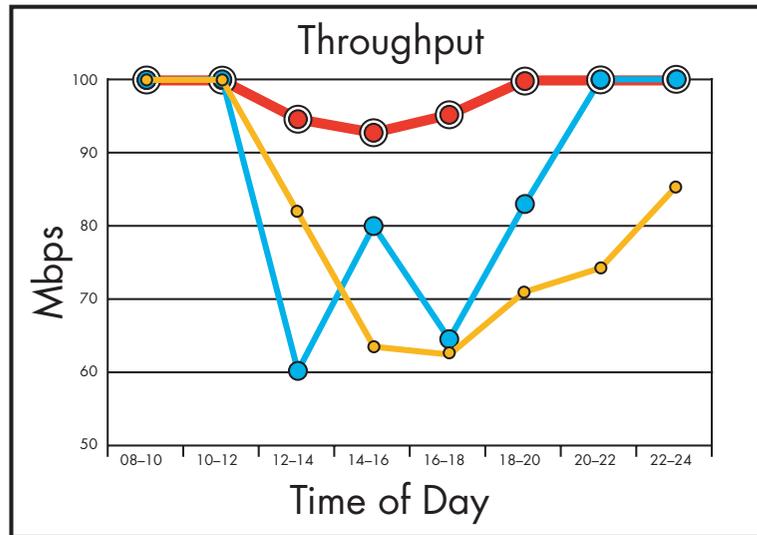
	Local	National	International
Throughput	100 Mbps	100 Mbps	100 Mbps
Delay	1 ms	40 ms	93 ms
Packet loss	0%	0.02%	0.31%
Jitter	0 ms	0 ms	2 ms

Stanford – Australia:
1 Gbps, 12 hops

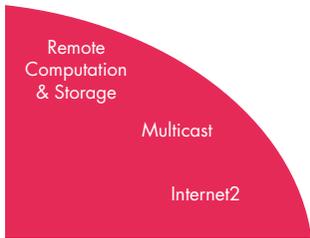
- Chariot software at endpoints
 - Test packets: 1500 bytes at 70 Mbps

Network Traffic: Time of Day

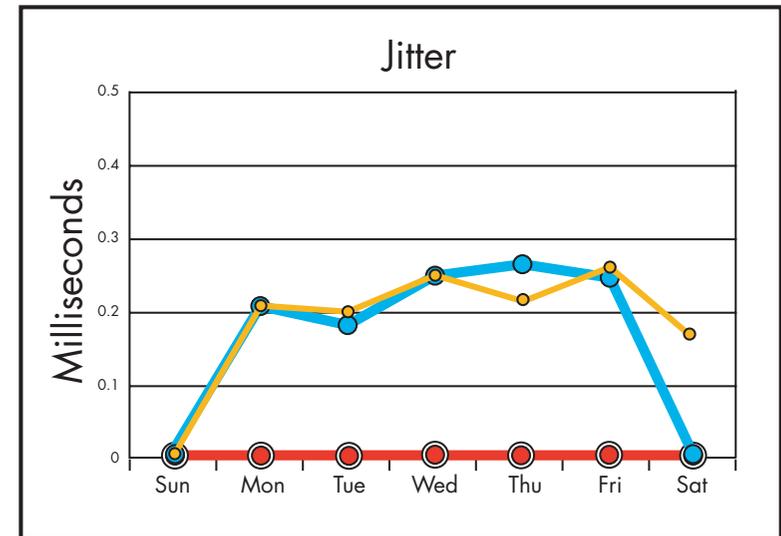
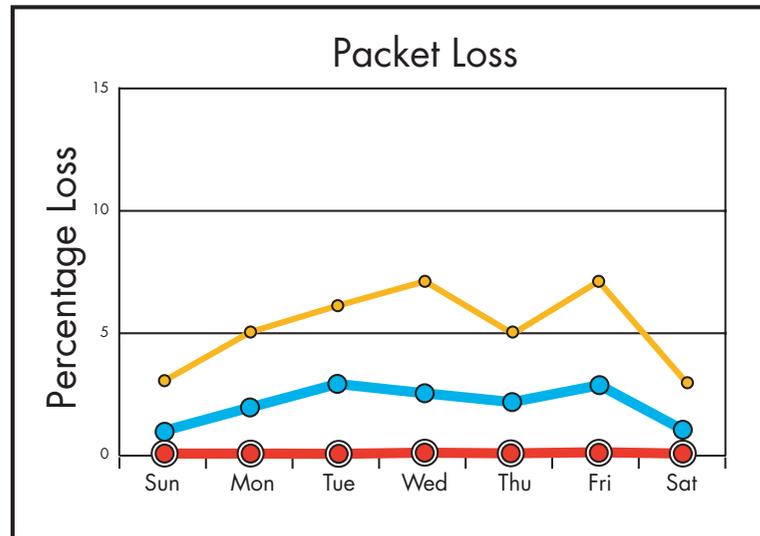
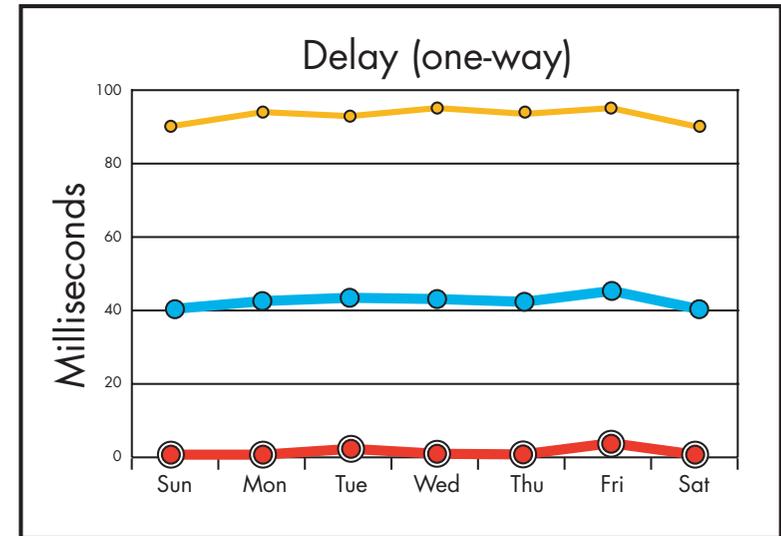
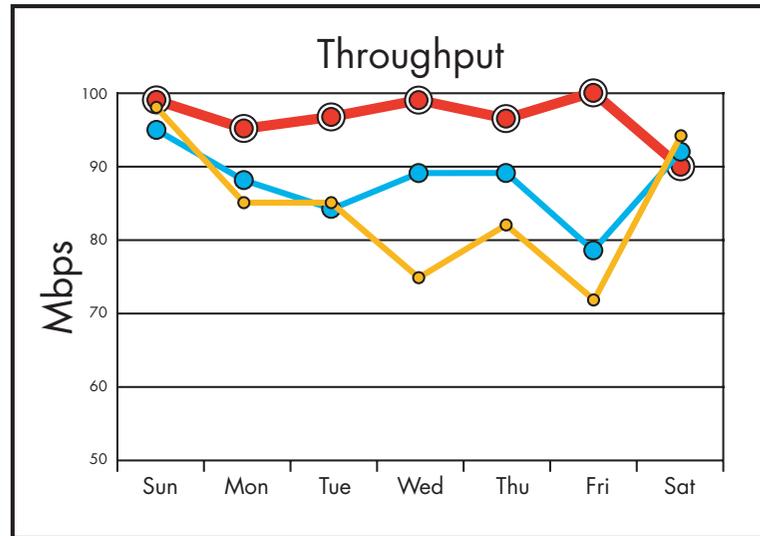
-  Local
-  National
-  International



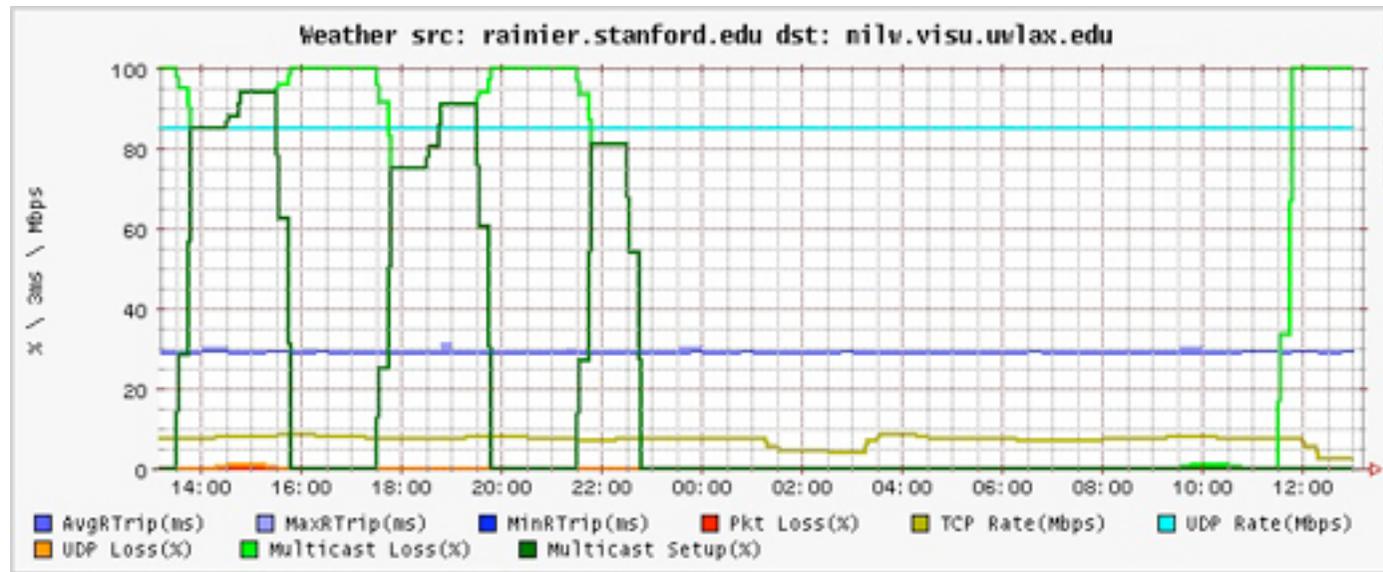
Network Traffic: Day of Week



- Local
- National
- International

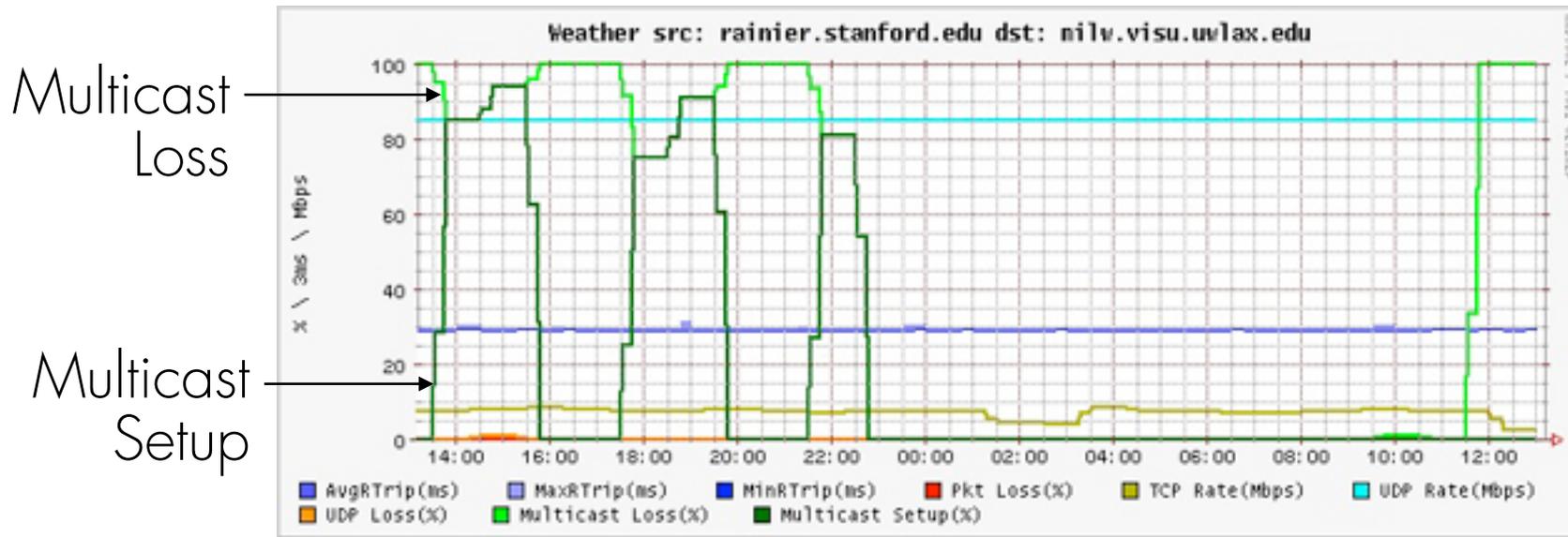
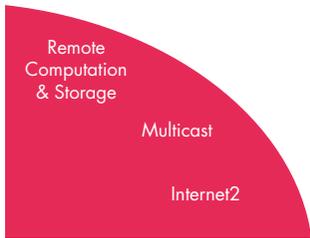


Network Traffic: Multicast



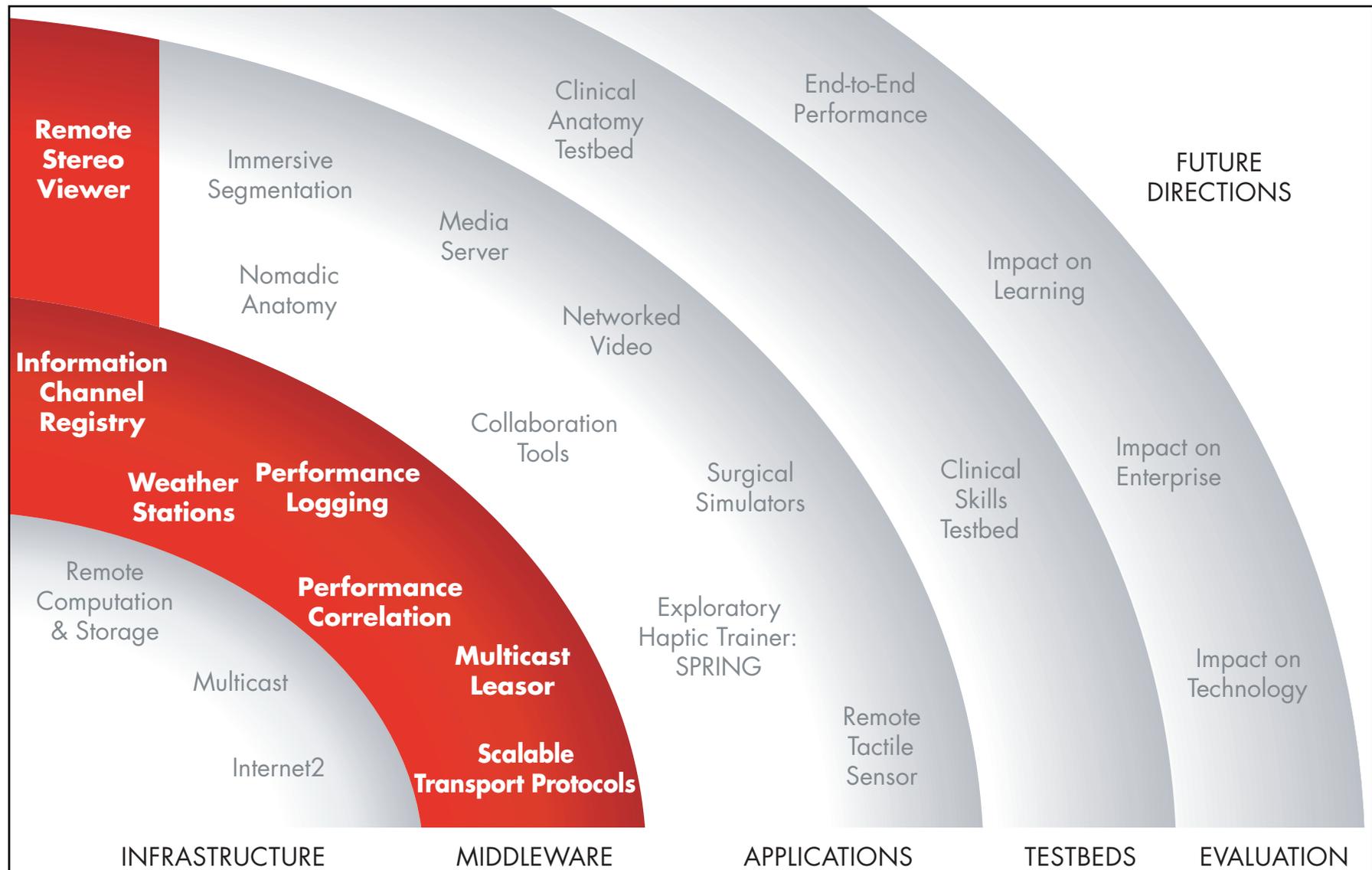
- Multicast is essential for networked collaboration
 - Multicast protocols are not implemented uniformly

Network Traffic: Multicast

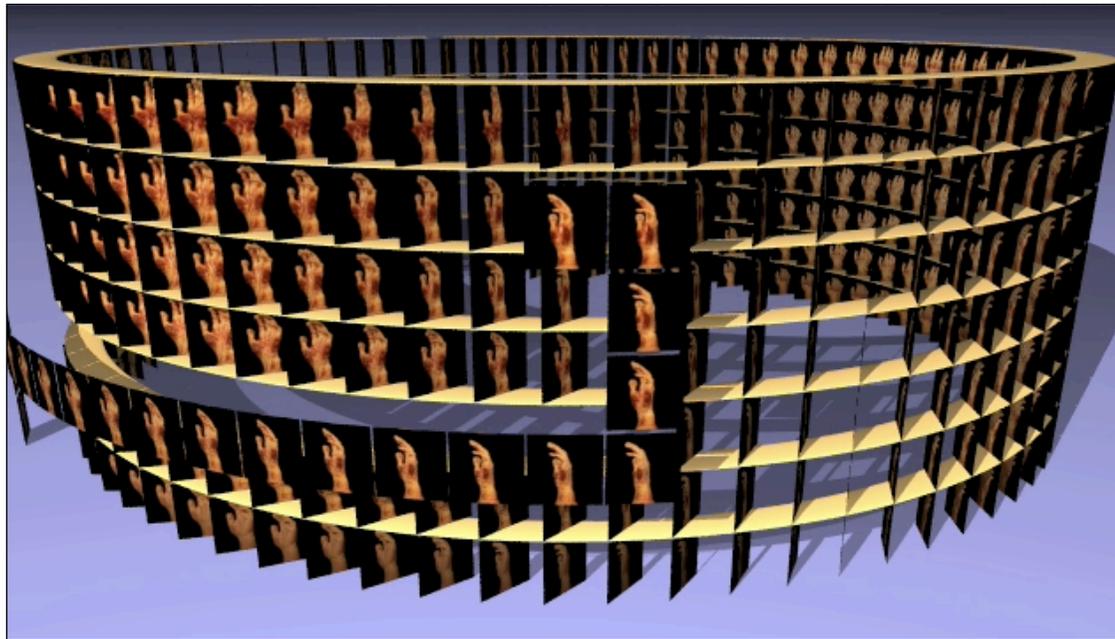
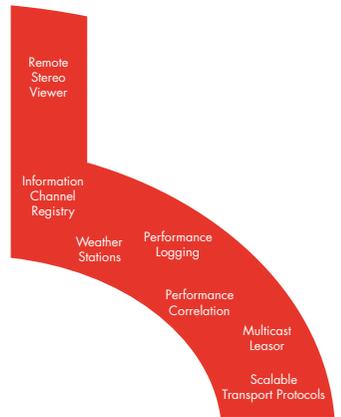


- Multicast is essential for networked collaboration
 - Multicast protocols are not implemented uniformly

Middleware



Accessing Image Sets



- Large, multi-dimensional image sets
- Free navigation
- On-demand image transport
 - High bandwidth bursts



Accessing Image Sets

Remote
Stereo
Viewer

Information
Channel
Registry

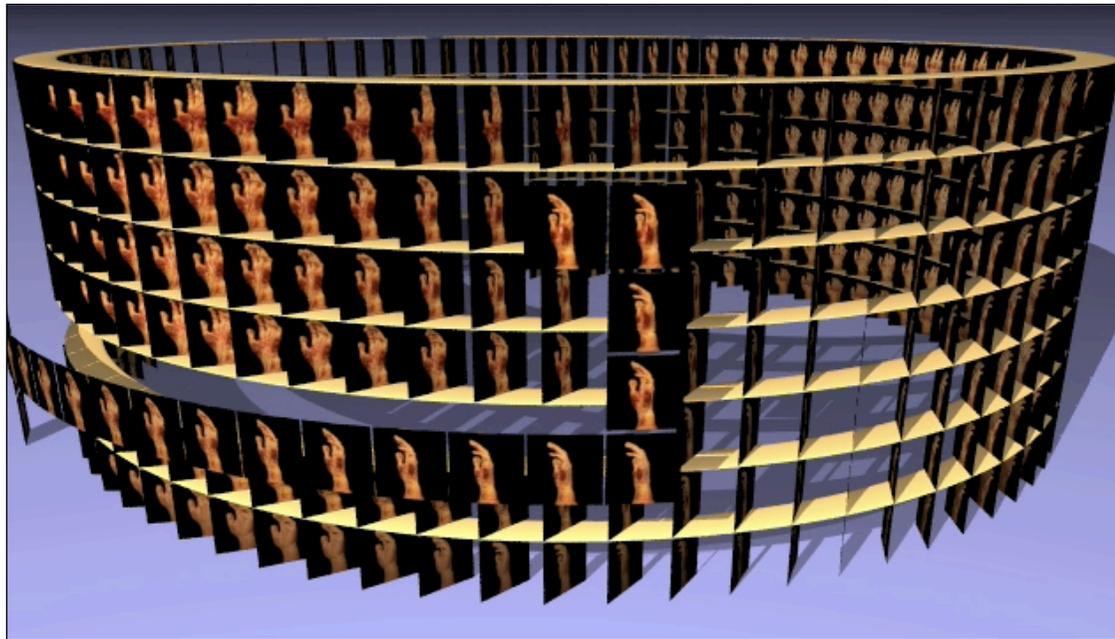
Weather
Stations

Performance
Logging

Performance
Correlation

Multicast
Leasor

Scalable
Transport Protocols



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Accessing Image Sets

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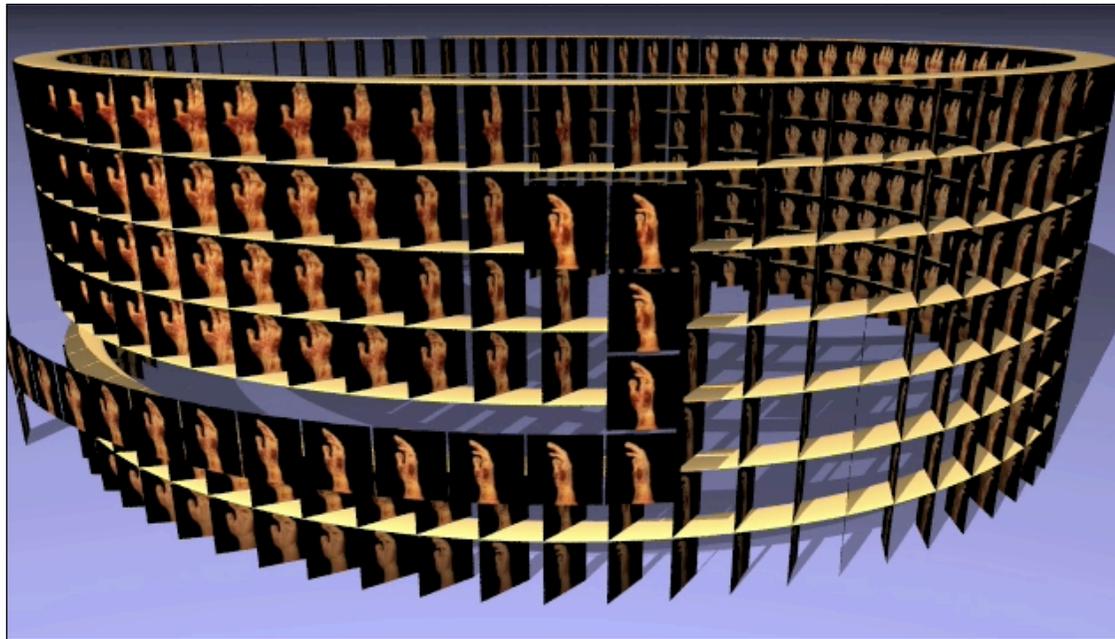
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Weather Stations

Remote
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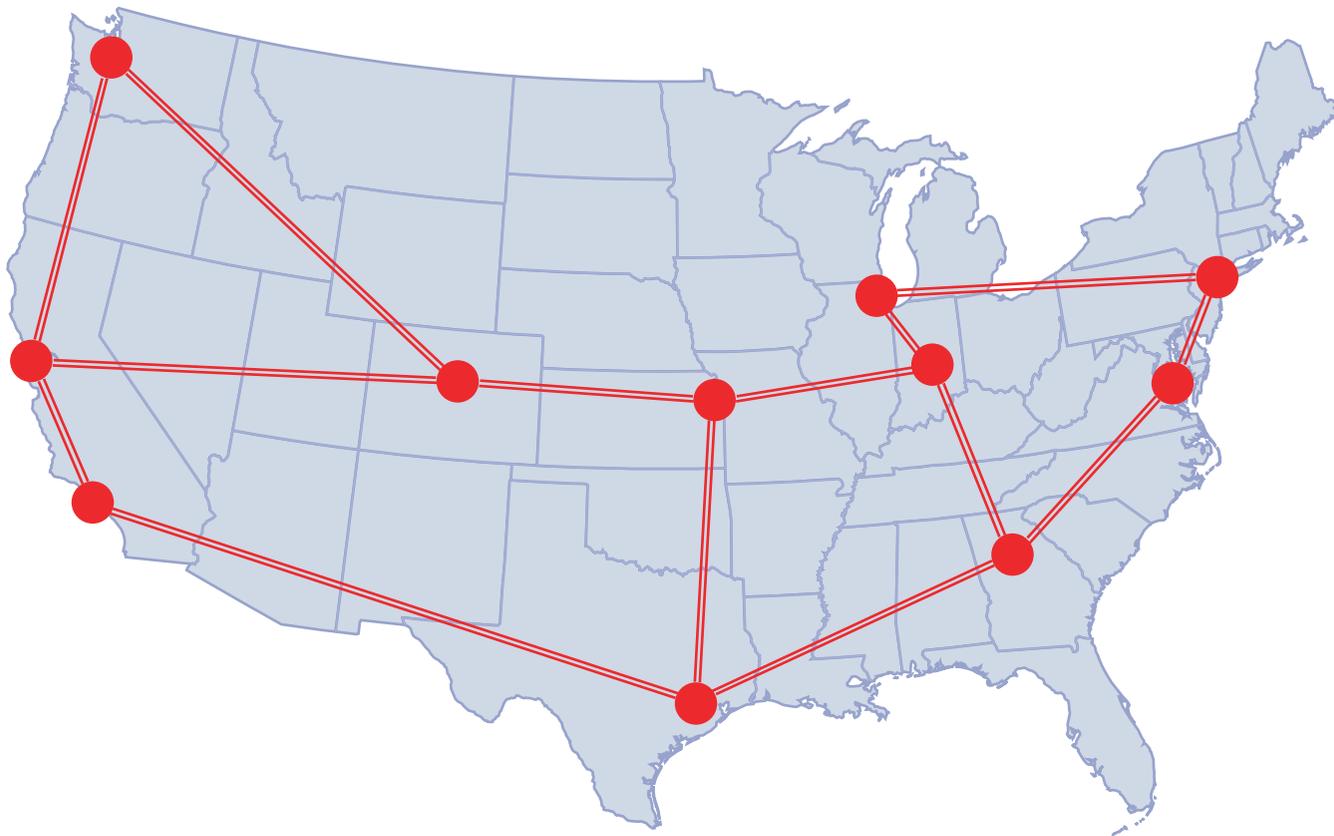
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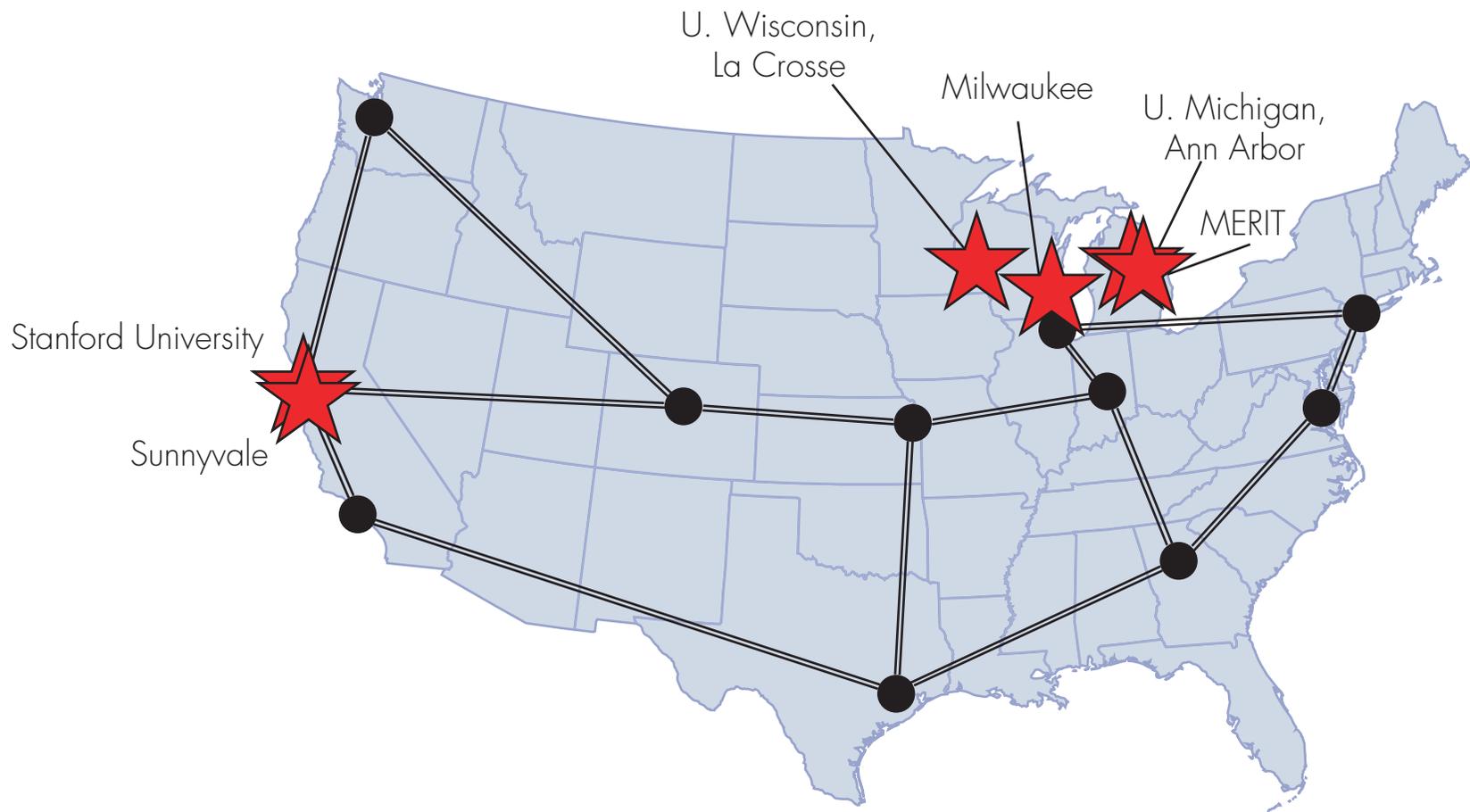
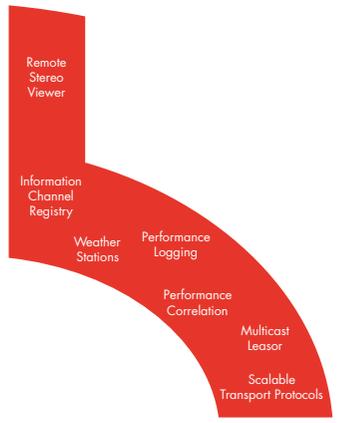
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Weather Stations



Weather Stations

Remote
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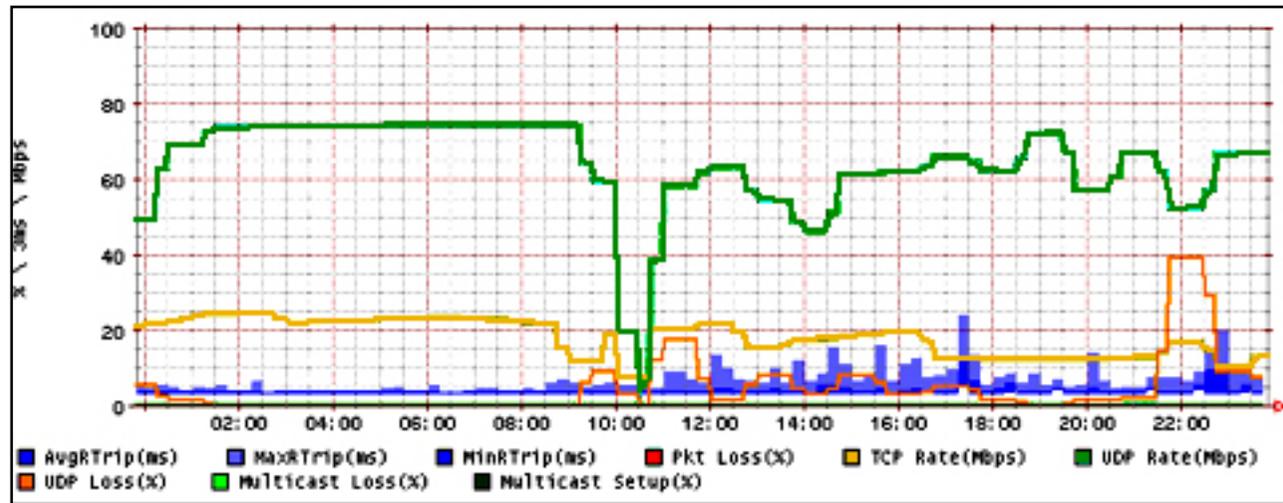
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Transport Protocols



- Measure network metrics
 - TCP, UDP, Multicast
- Schedule periodic tests with peers
 - Results logged to performance database

Weather Stations

Remote
Stereo
Viewer

Information
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Weather
Stations

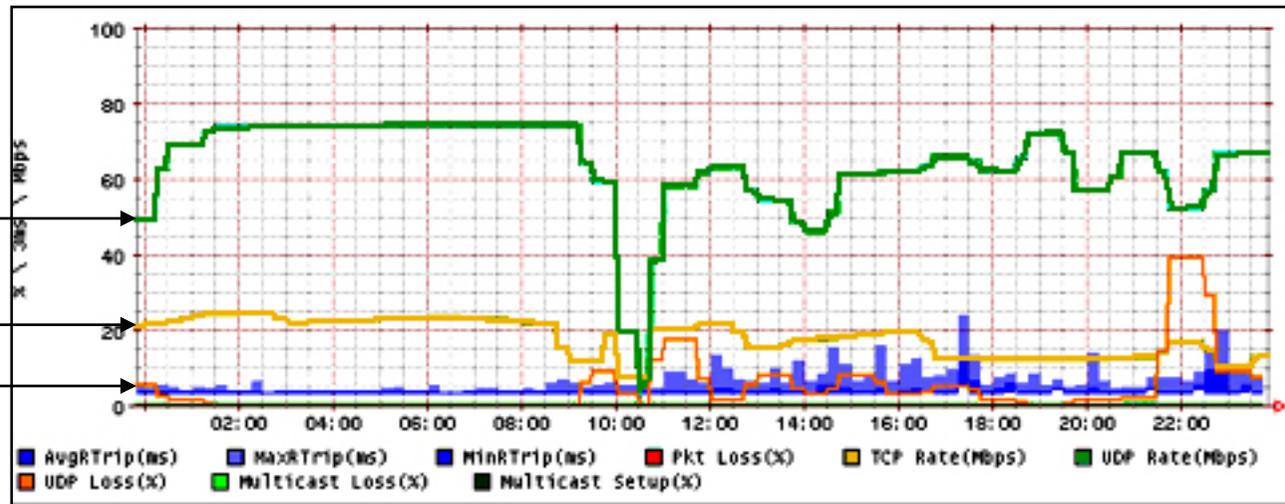
Performance
Logging

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Correlation

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Scalable
Transport Protocols

UDP Rate
TCP Rate
Latency



- Measure network metrics
 - TCP, UDP, Multicast
- Schedule periodic tests with peers
 - Results logged to performance database

Weather Stations

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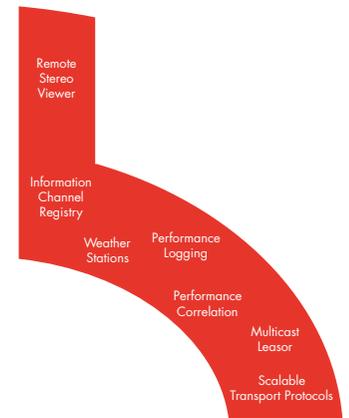
Multicast
Leasor

Scalable
Transport Protocols



- Network traffic statistics are gathered every hour and are accessible at <http://peabrain.visu.uwlax.edu/WthrStns/v2/>

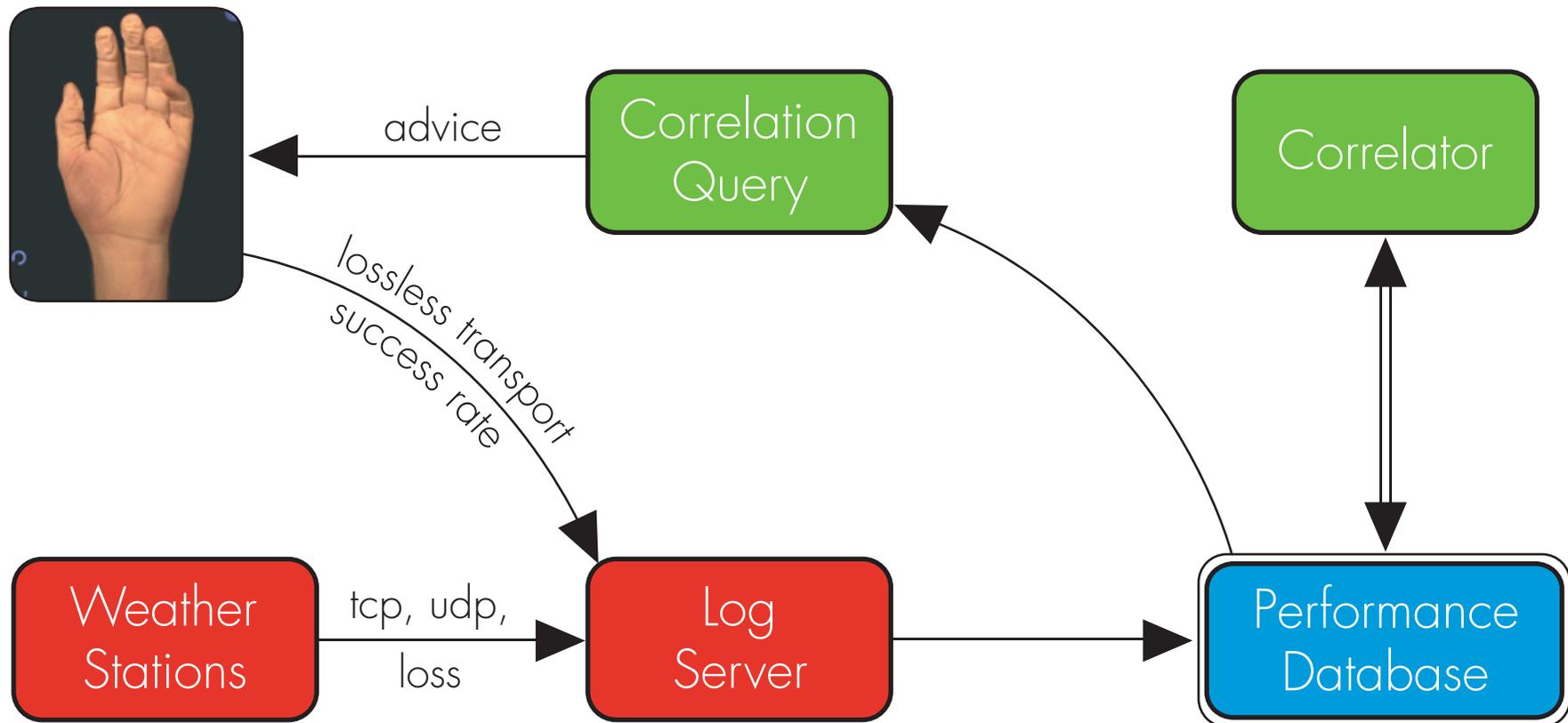
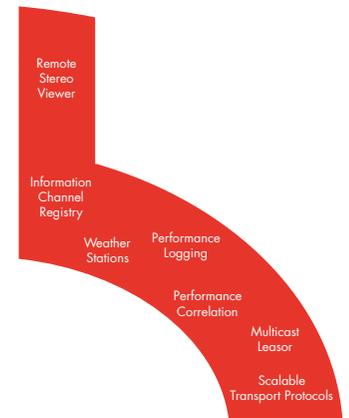
Performance Logging



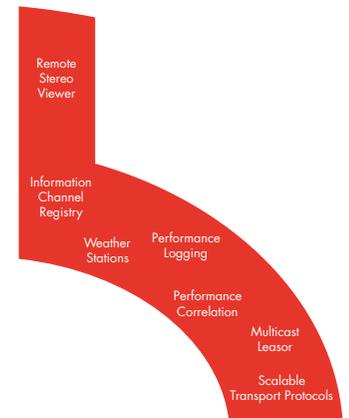
*lossless transport
success rate*



Performance Correlation

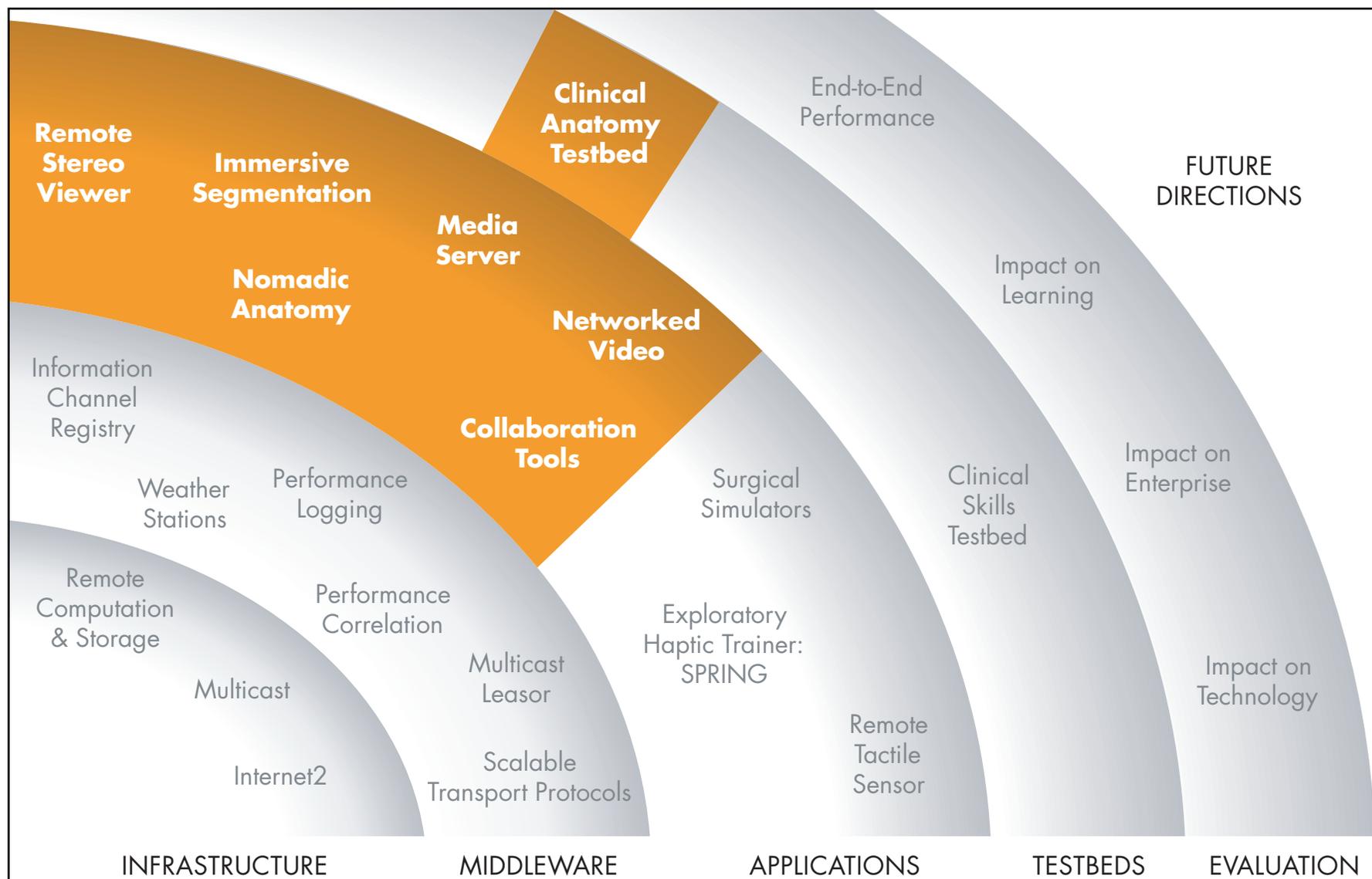


Scalable Transport

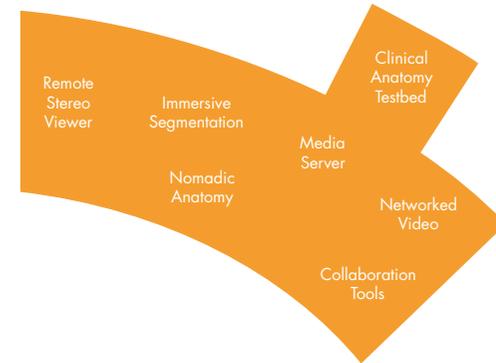


- Unique characteristics for each application determine possible scalable behaviors
 - options for scaling RSV are:
 - * Send rate, image resolution, prefetch
 - Past experience used to “seed” behavior
 - Past experience provides feedback to user
- Respond to network congestion and non-congestive loss

Clinical Anatomy Testbed

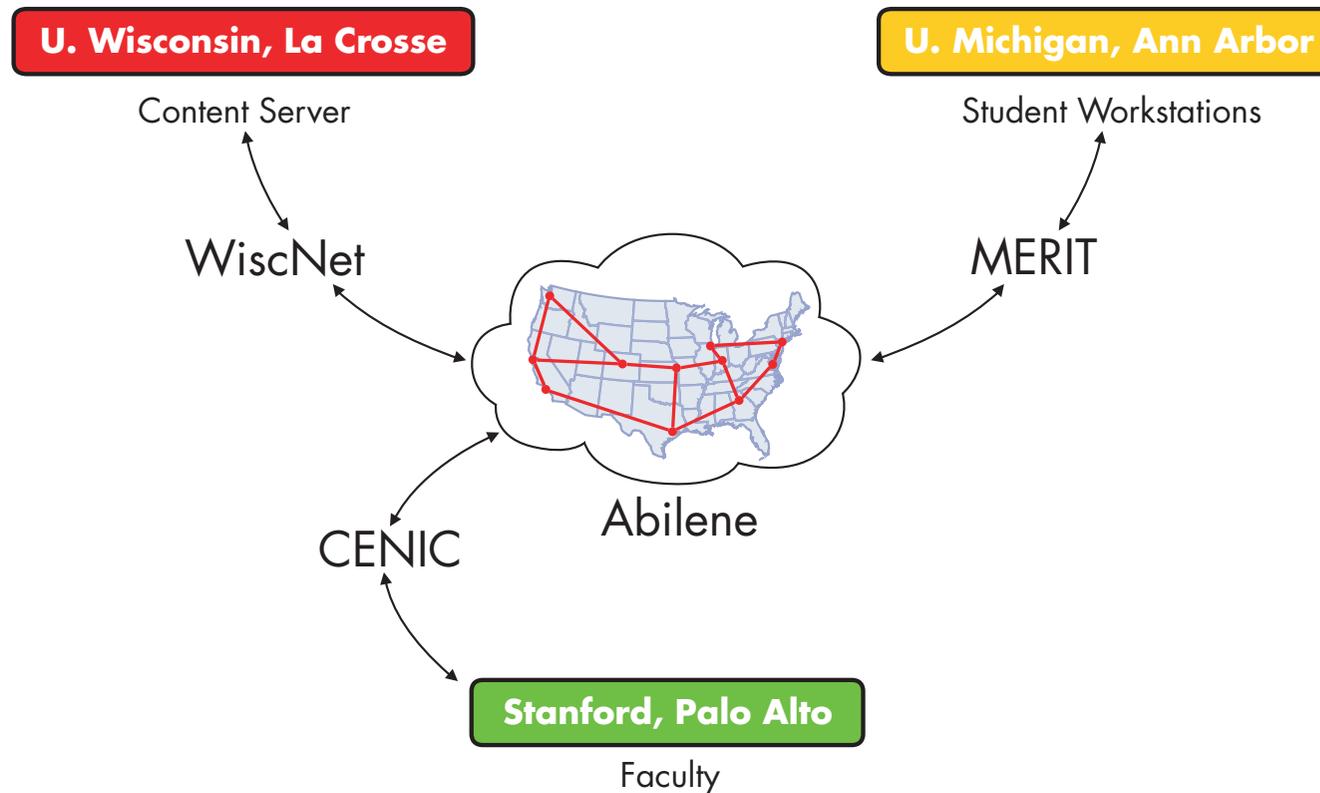
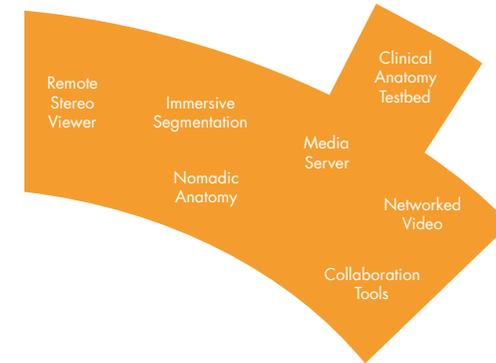


Clinical Anatomy Testbed



- Local Testbed
 - lab test between SUMMIT Lab & Stanford anatomy classrooms
- National Testbed
 - lab test between Stanford University and University of Michigan
- International Testbed
 - field test between Stanford and Northern Ontario School of Medicine
 - demonstrations at Internet2, NLM, Korea, Latin America & World Bank Global Development Learning Network Sites

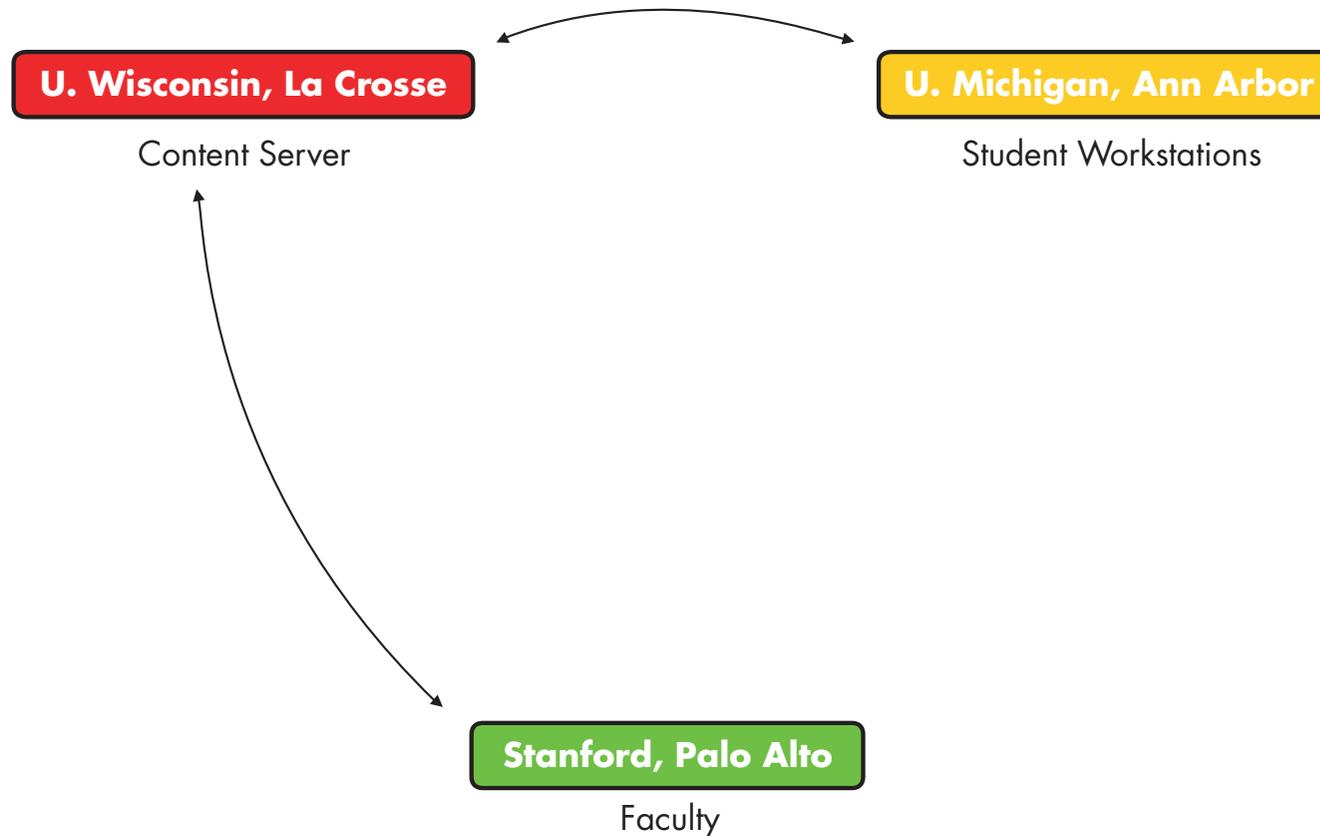
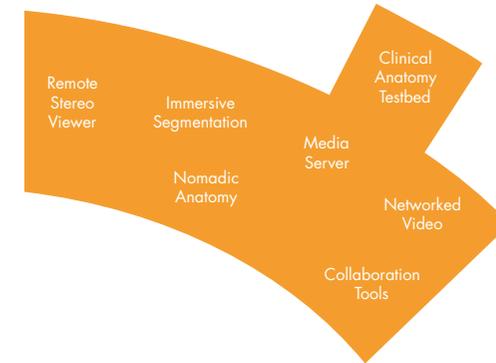
National Testbed



- Testbed between Stanford, University of Michigan, Ann Arbor & University of Wisconsin, La Crosse

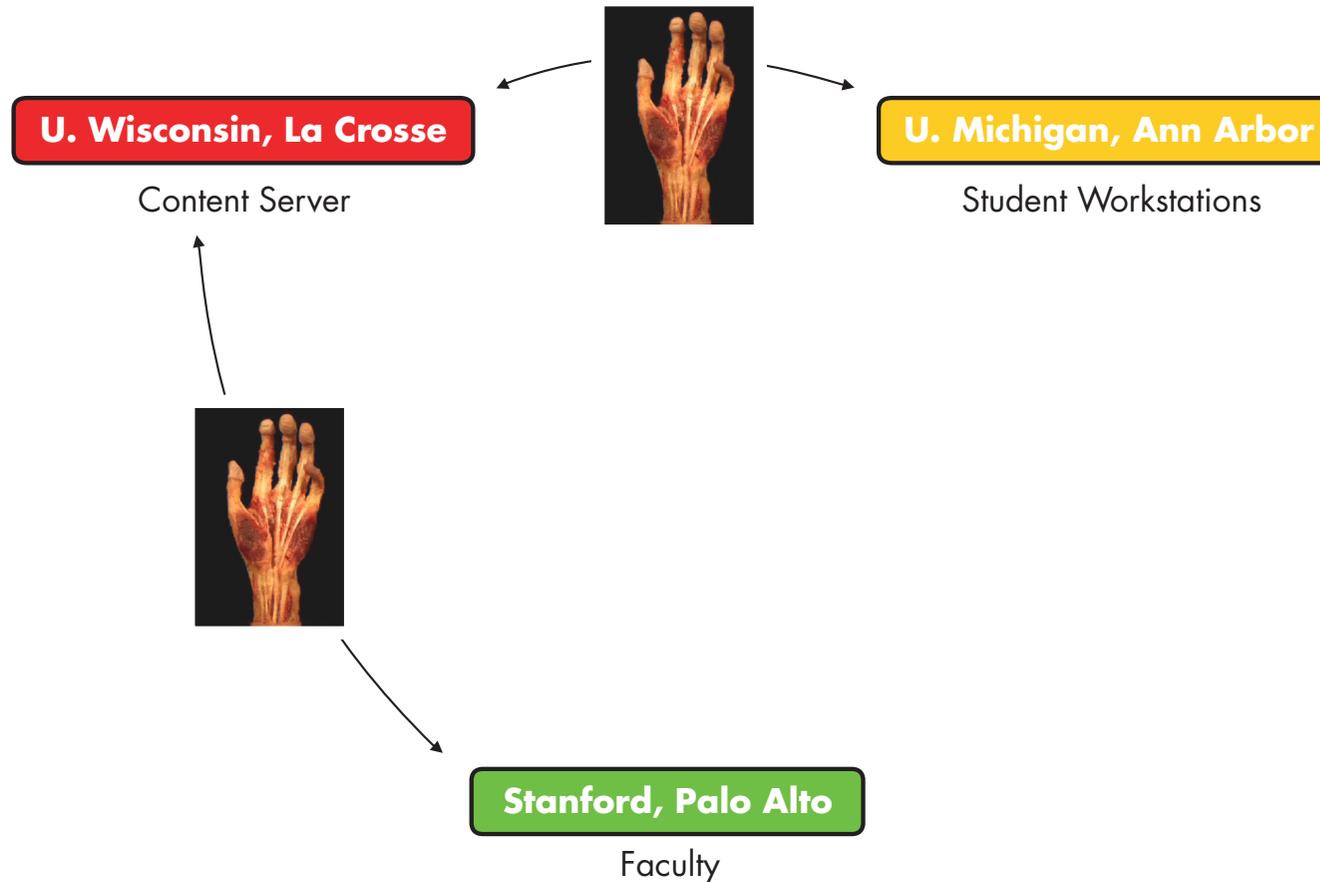
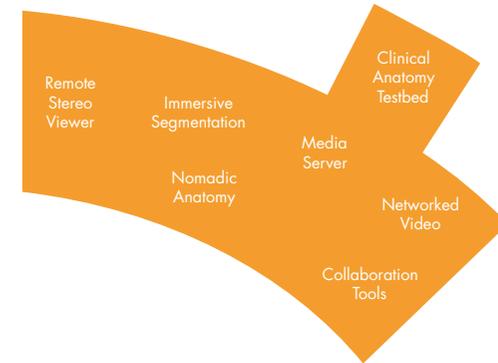
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Clinical Anatomy Testbed



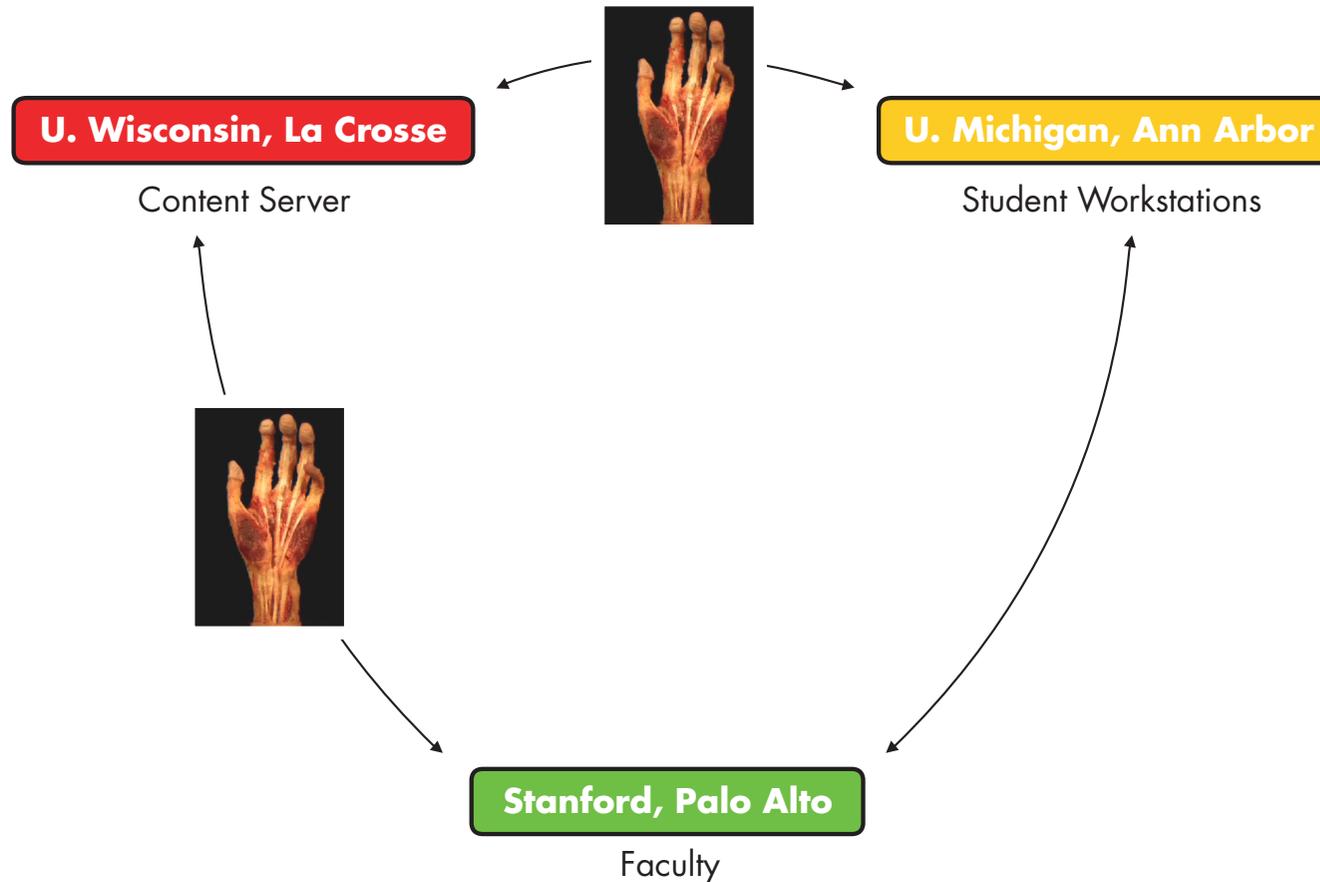
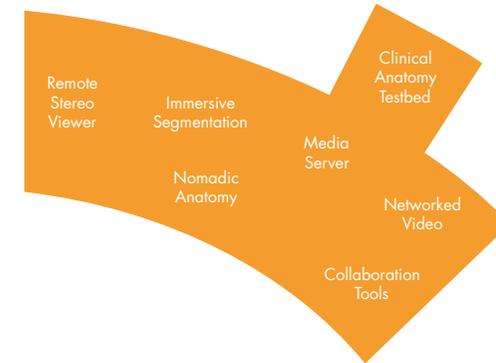
- Content at Wisconsin is accessed by students in Michigan and faculty at Stanford

National Testbed



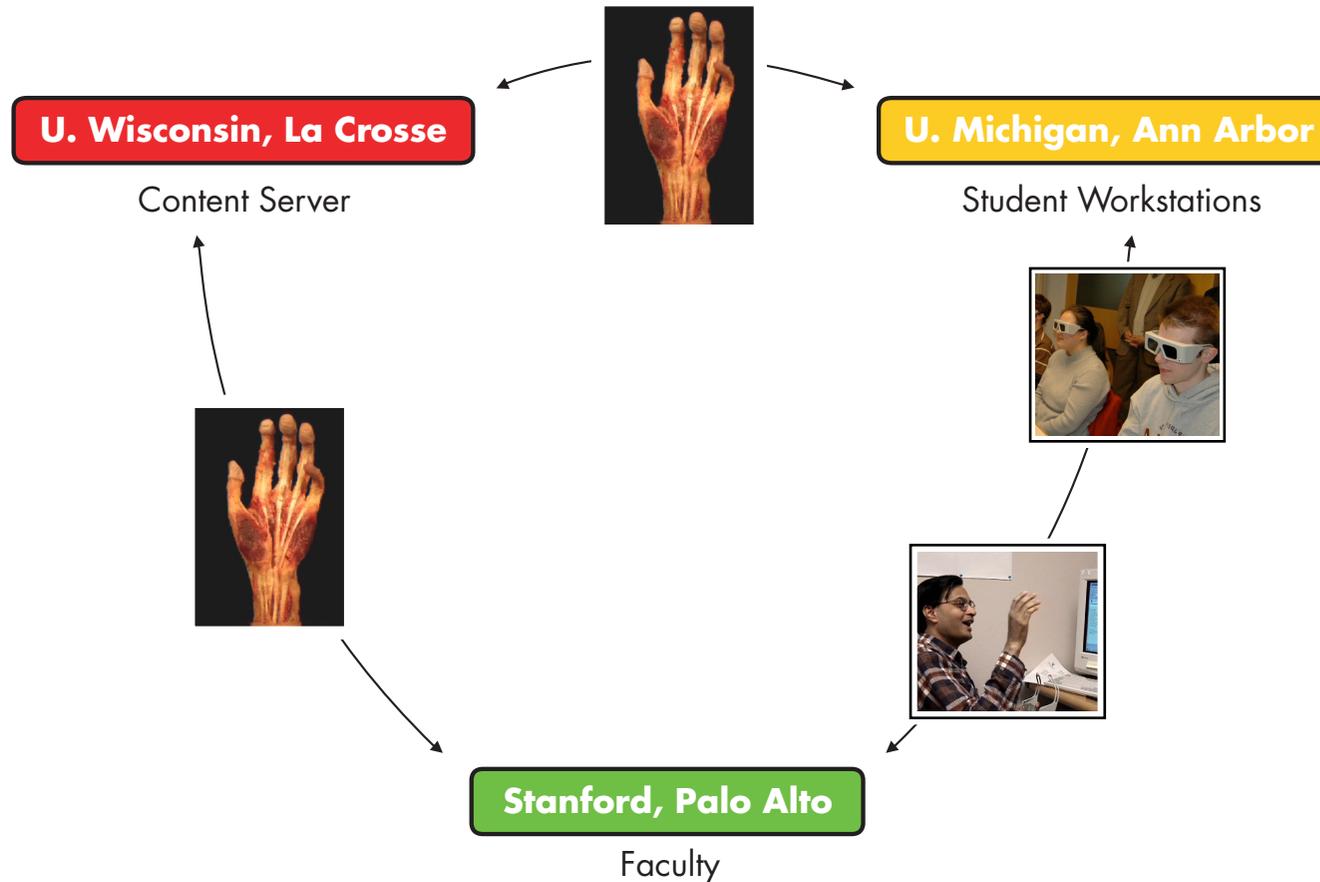
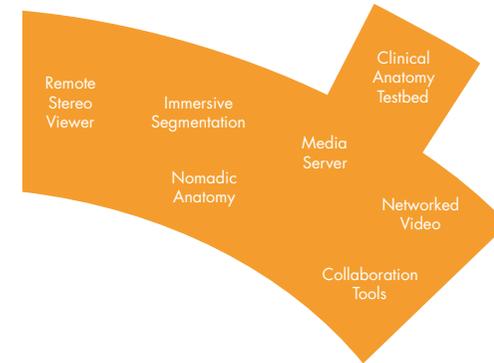
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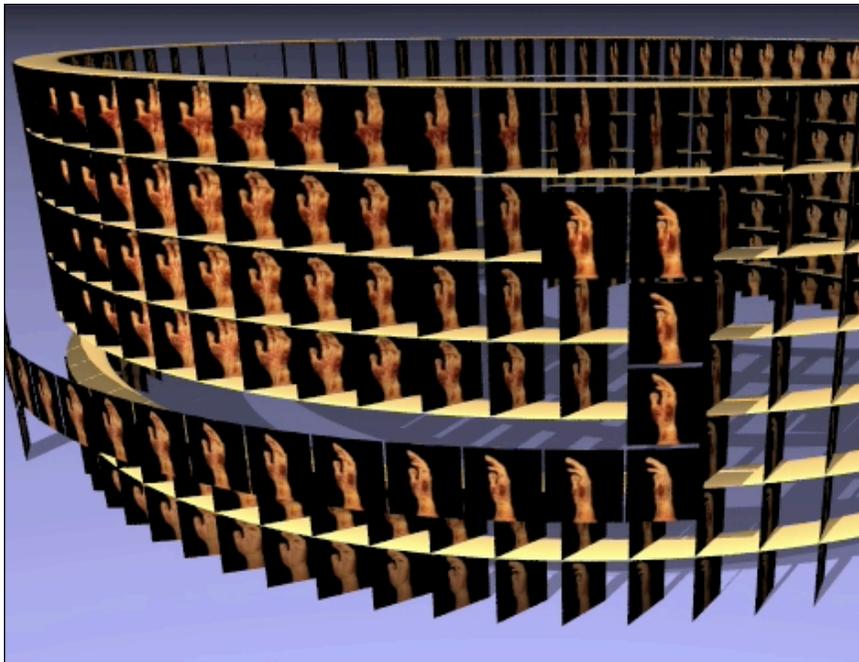
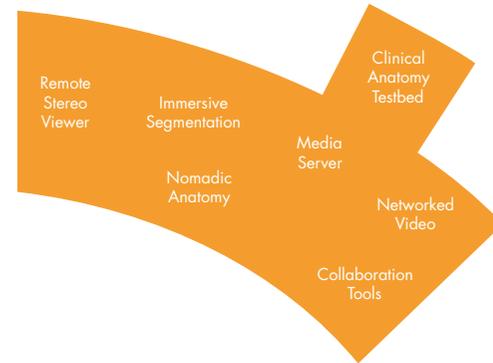
- Faculty and students interact with each other through video collaboration

National Testbed



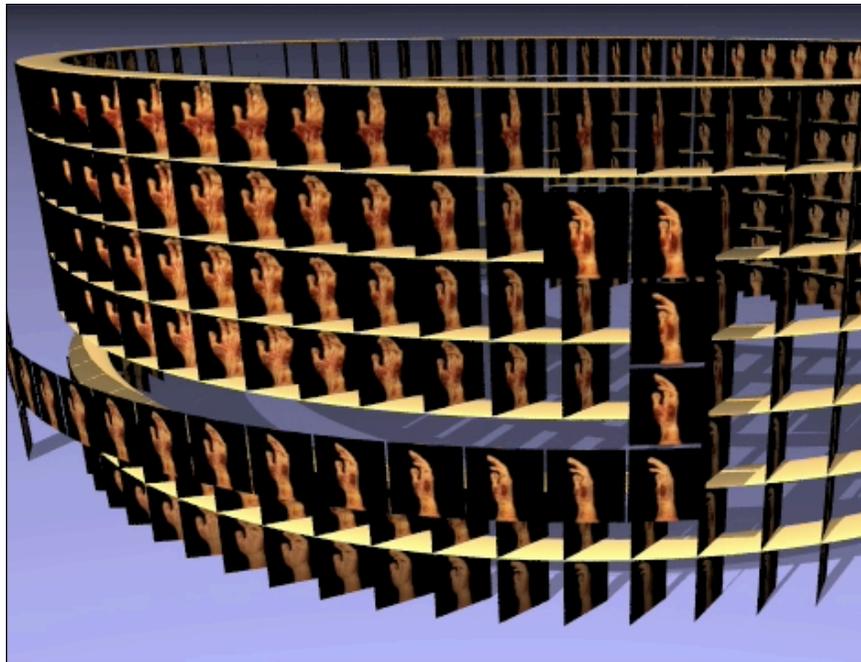
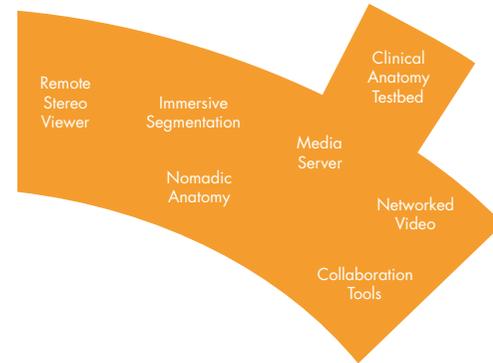
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Rich Media Resources



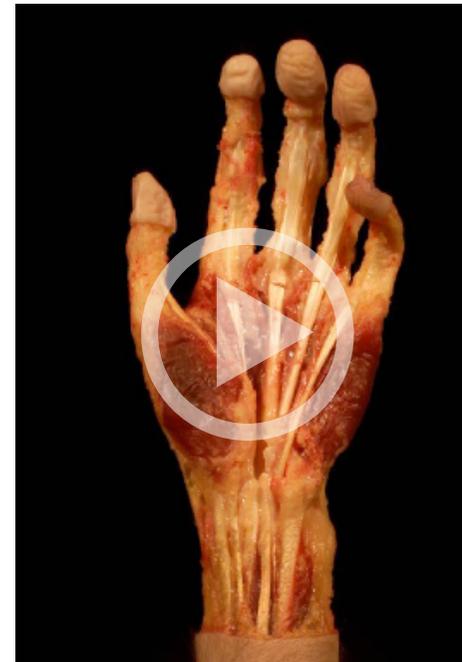
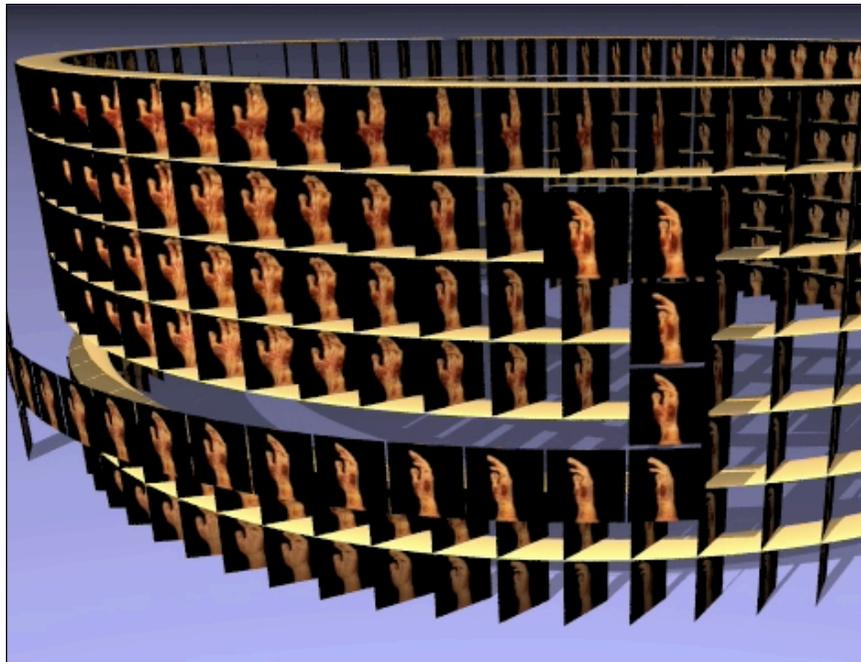
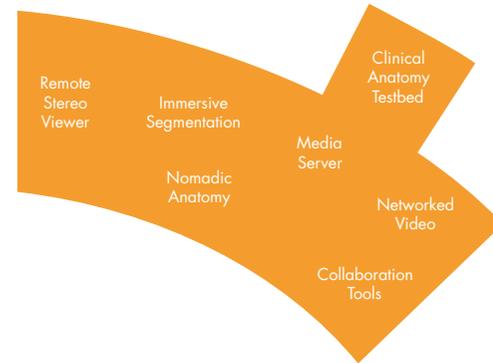
- Richly linked data sets support student exploration of dissections

Rich Media Resources



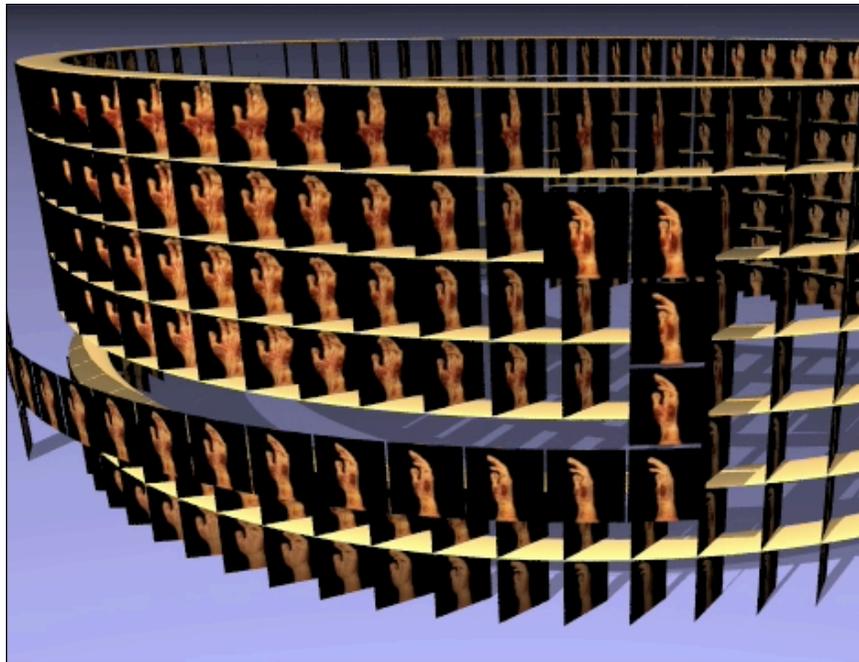
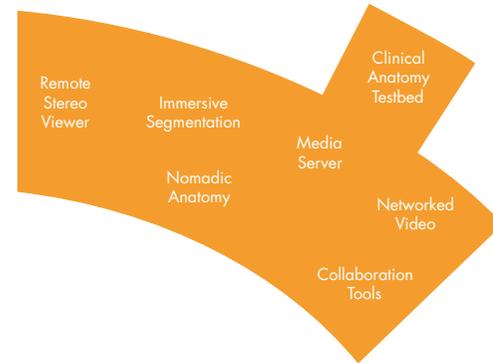
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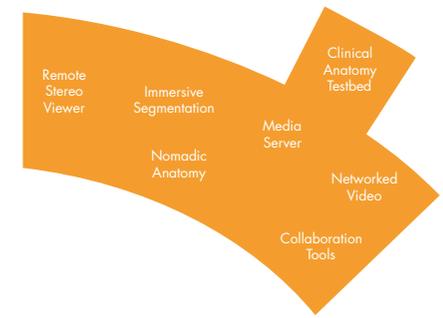
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Rich Media Resources



- Richly linked data sets support student exploration of dissections

Teaching with Remote Stereo Images

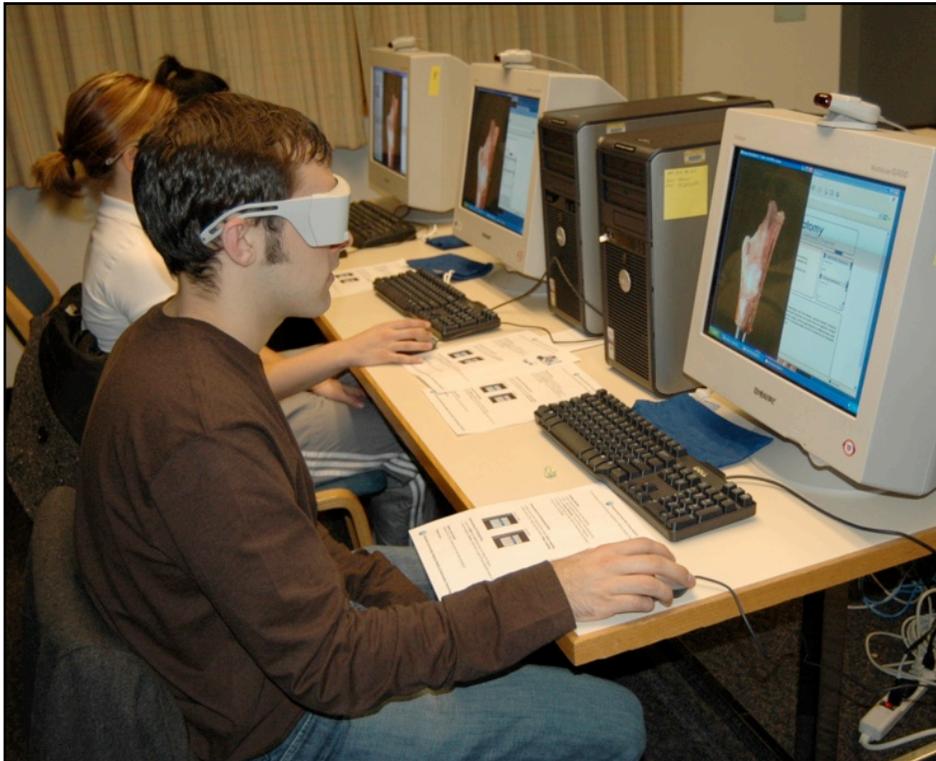
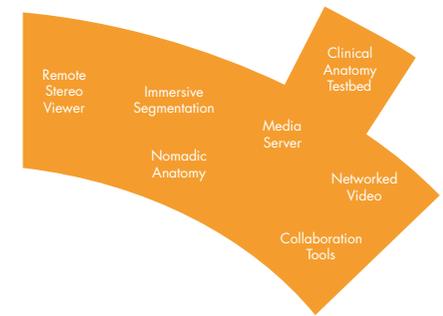


Learning Resource Center
at University of Michigan

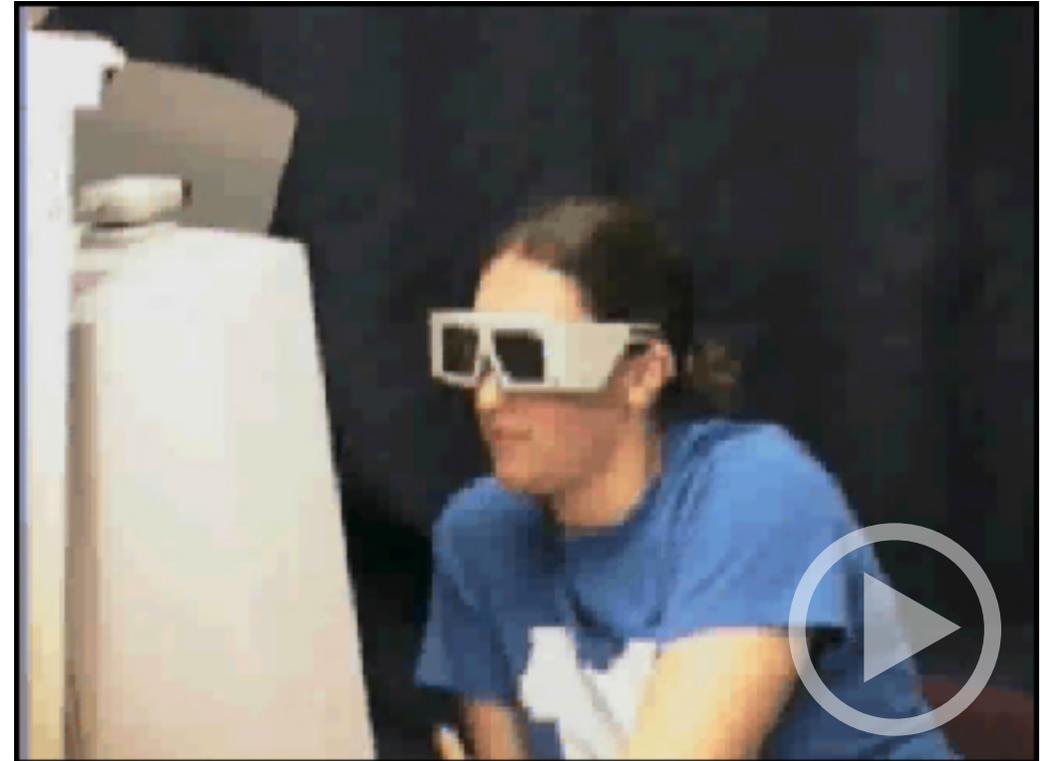
Catey Bradford, Teaching
Assistant at Stanford University

- A distributed learning session on anatomy of the knee

Teaching with Remote Stereo Images



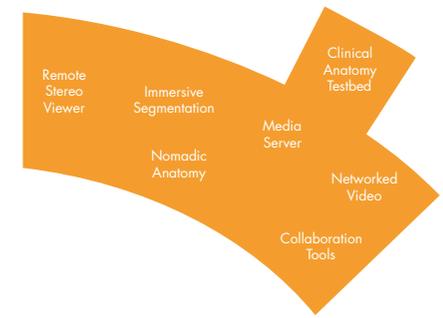
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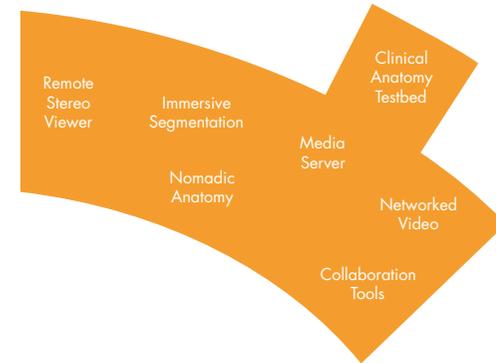
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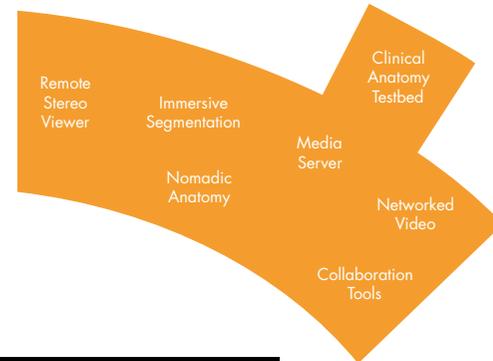
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Response to Interactive Images



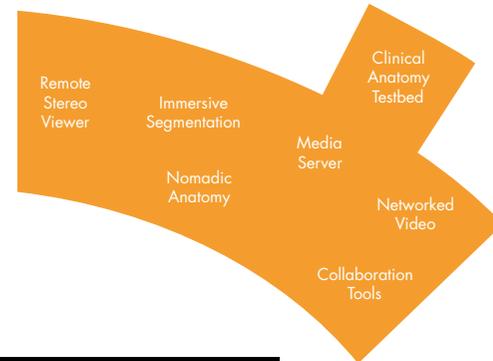
- University of Michigan students work with Stanford teachers via the Remote Stereo Viewer

Response to Interactive Images



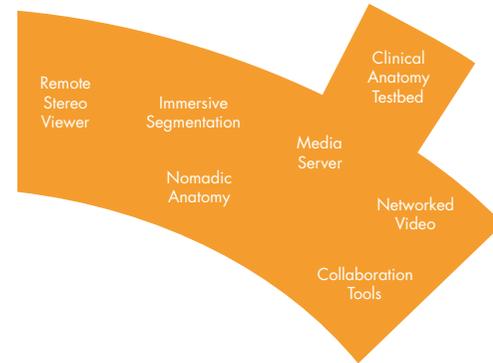
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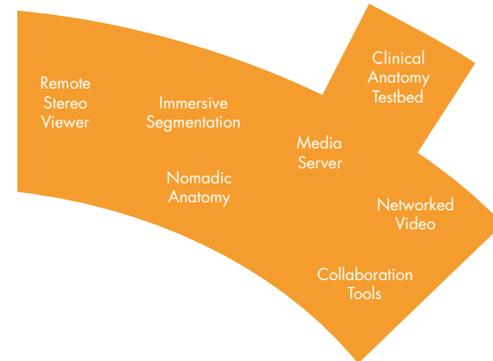
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Issues in Testbed Deployment



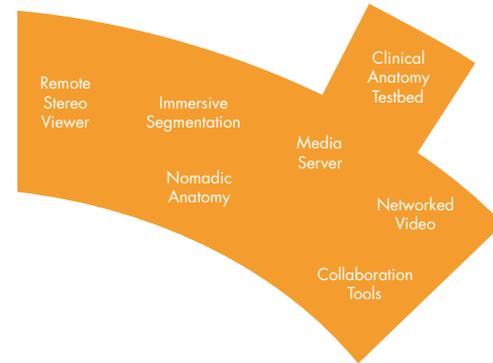
- Success requires integrated effort by teams along the entire network

Issues in Testbed Deployment



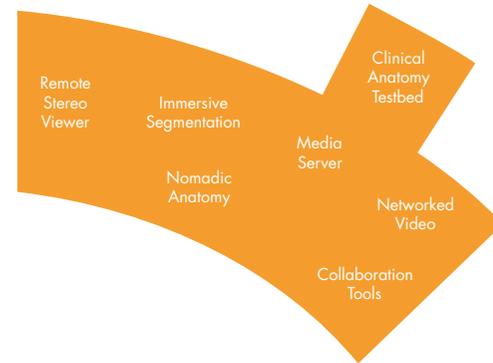
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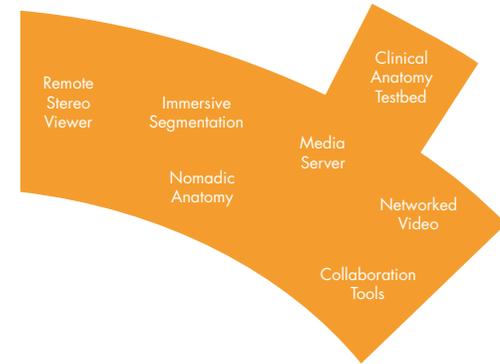
- Success requires integrated effort by teams along the entire network

Issues in Testbed Deployment



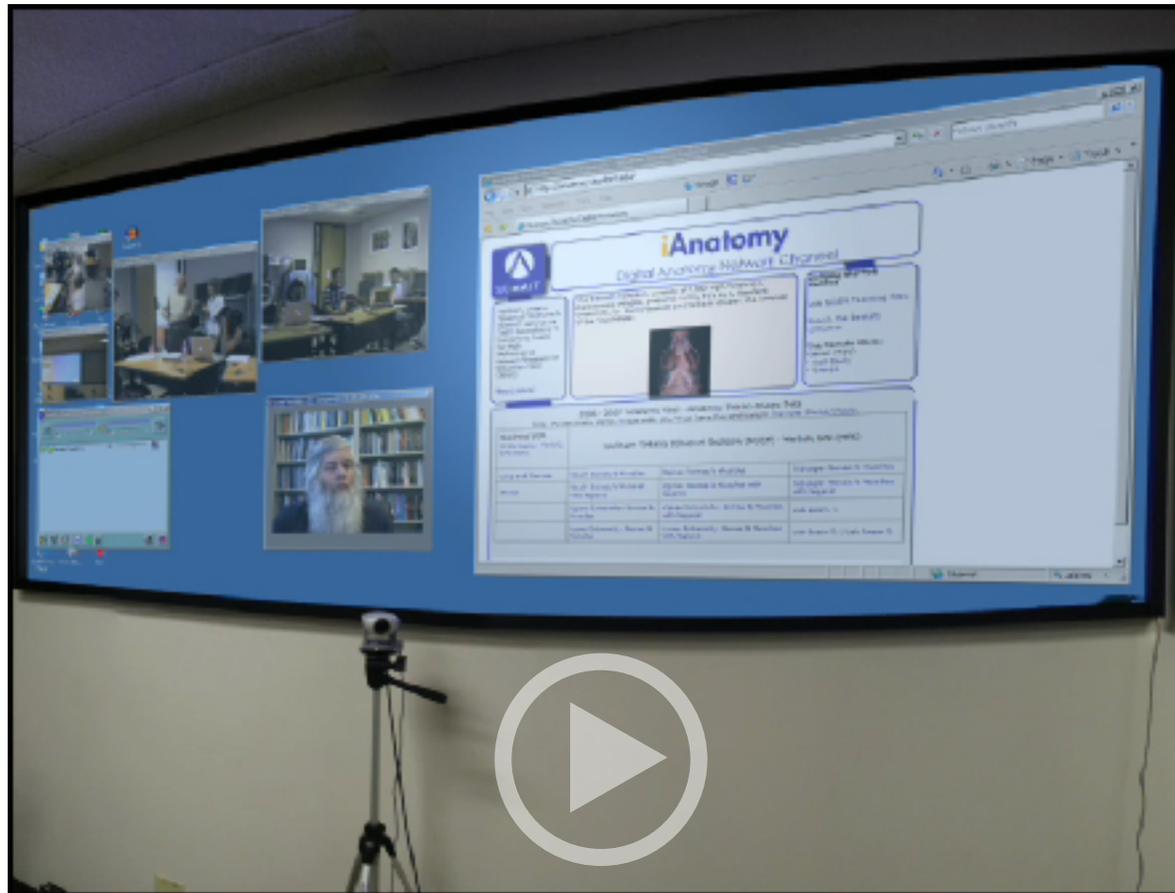
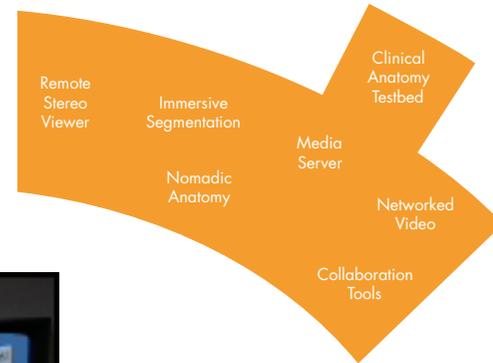
- Success requires integrated effort by teams along the entire network

Collab Room



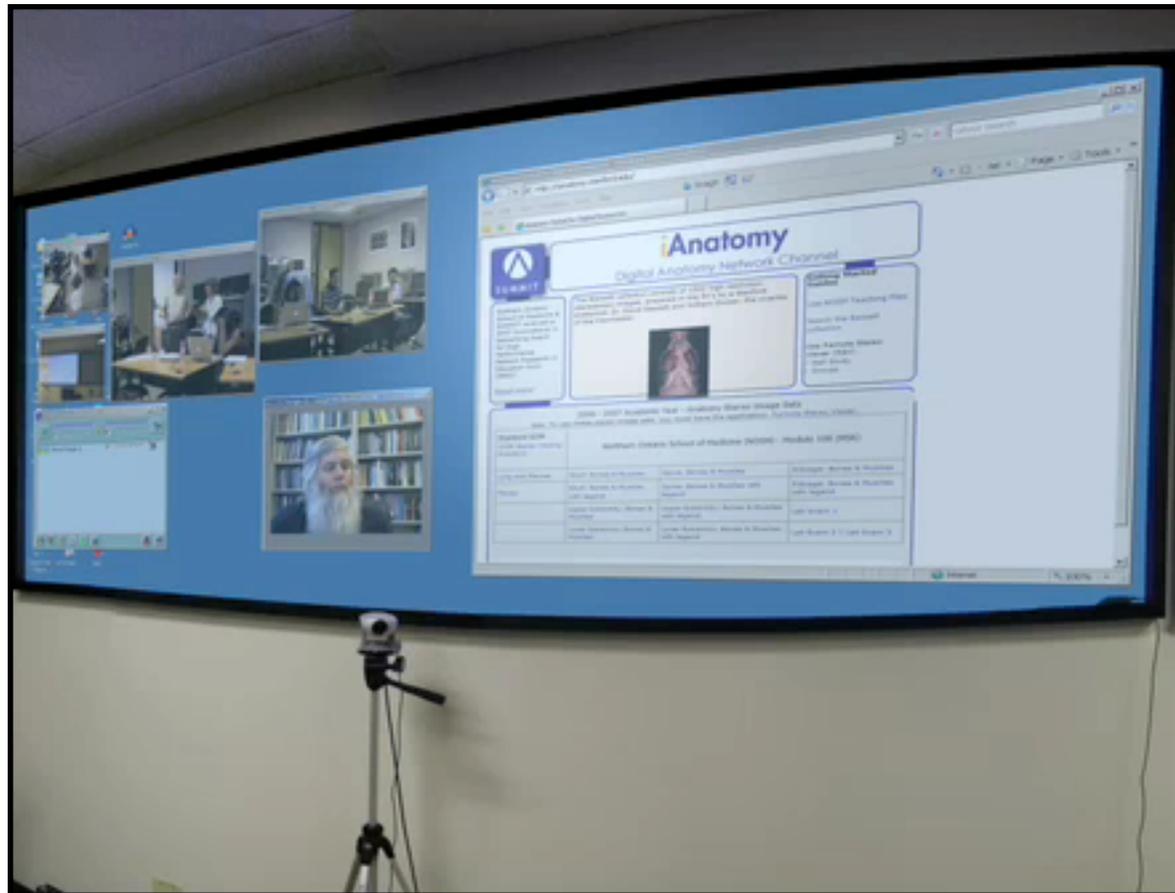
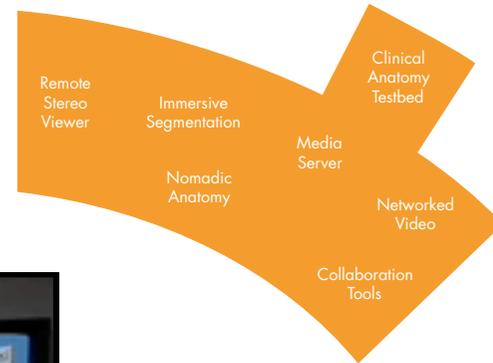
- Prototype of a collaborative classroom supporting media- and simulation-based teaching

Collab Room



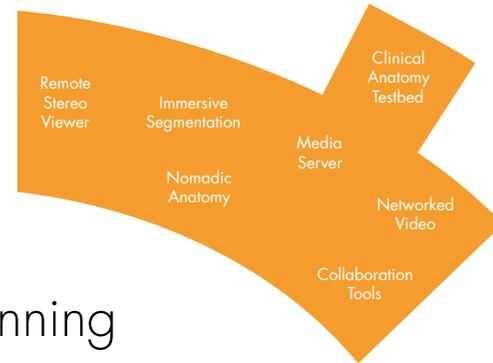
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Collab Room

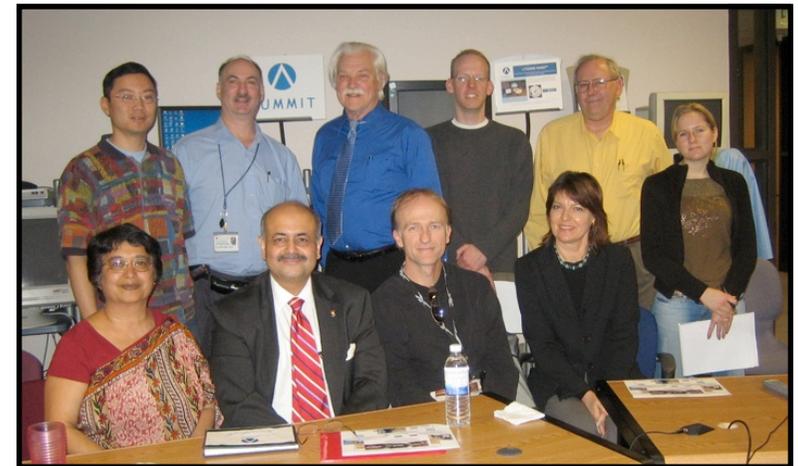
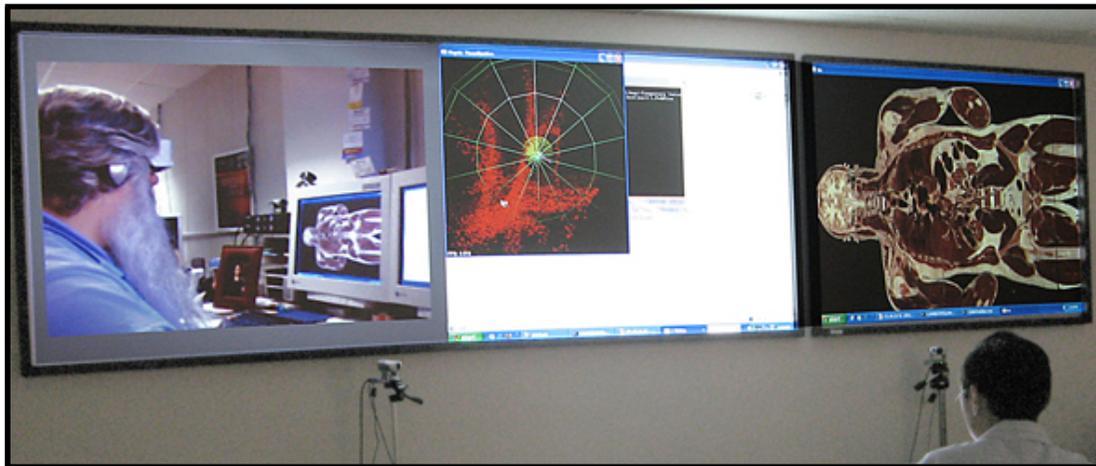


- Prototype of a collaborative classroom supporting media- and simulation-based teaching

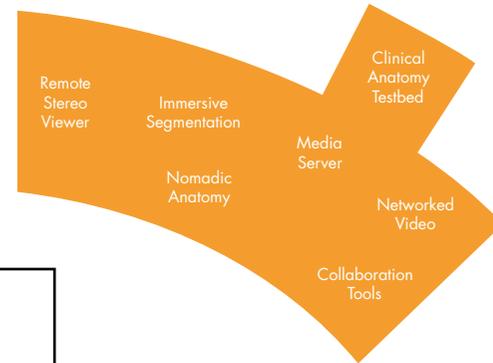
Uses of the Collab Room



- Annual visits & demos
 - 62 international visitors
 - 60 groups visits
 - 186 collaborative sessions
- Consulting interactions
 - 118 research consults for new projects
- Influence on institutional planning
 - lead to videoconferencing in other spaces
 - design of new simulation center
- Training with surgical simulators
 - 22 residents participate in simulator studies
- Remote teaching of anatomy
 - 90 Stanford students; 26 non-Stanford students

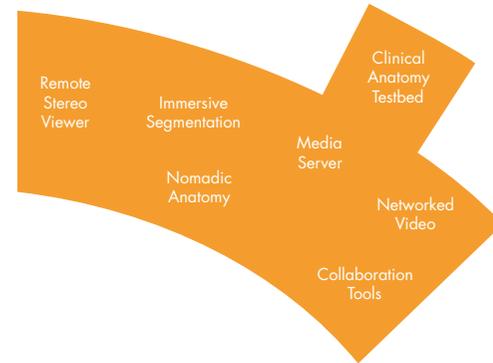


International Testbed



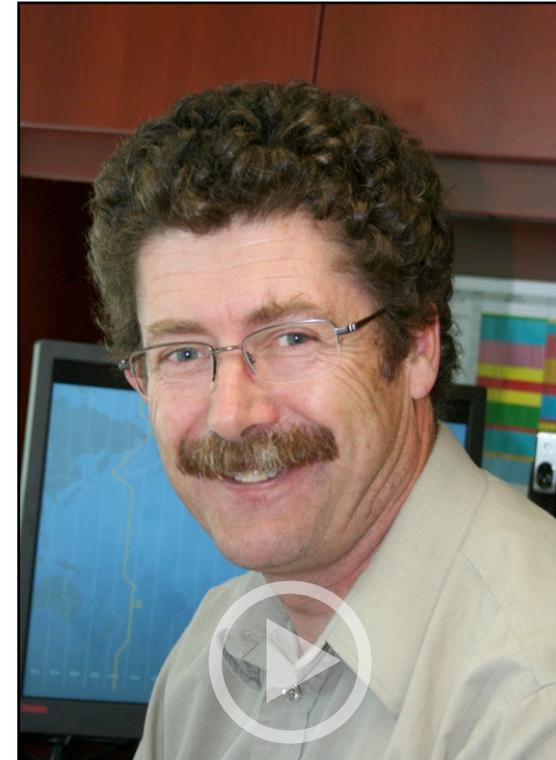
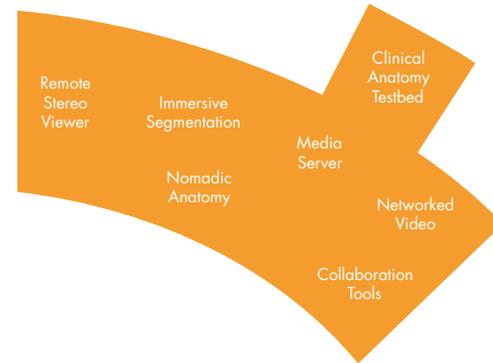
- Content from Stanford and Wisconsin is used by students at Northern Ontario School of Medicine's distributed medical campus in Thunder Bay and Sudbury

Northern Ontario School of Medicine



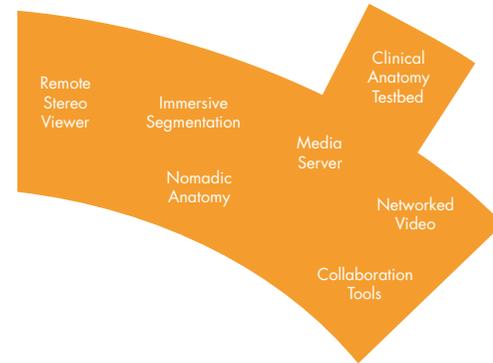
Dr. David Topps, NOSM's Director of e-Learning

Northern Ontario School of Medicine



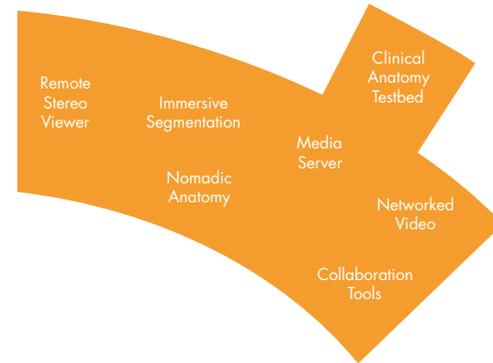
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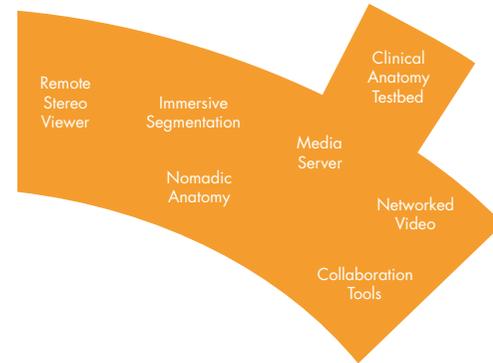
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International Networked Events



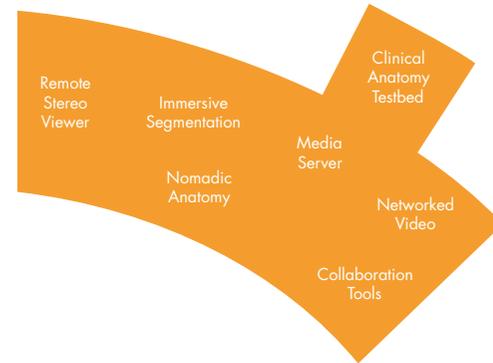
- Korea, Northern Ontario, Mexico, Venezuela, Brazil, Argentina, Columbia

International Networked Events



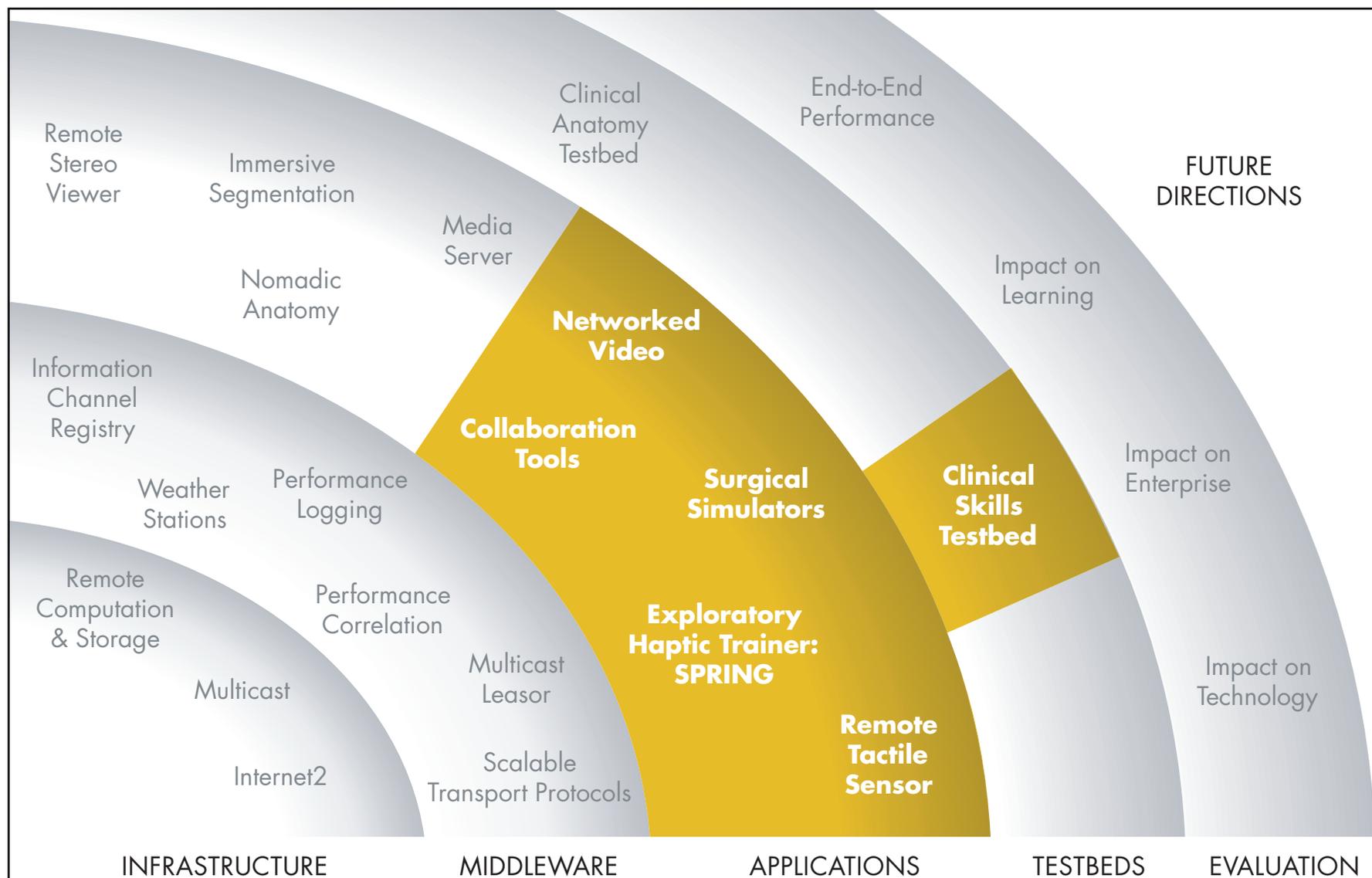
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International Networked Events



- Korea, Northern Ontario, Mexico, Venezuela, Brazil, Argentina, Columbia

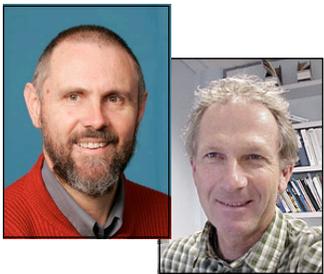
Clinical Skills Testbed



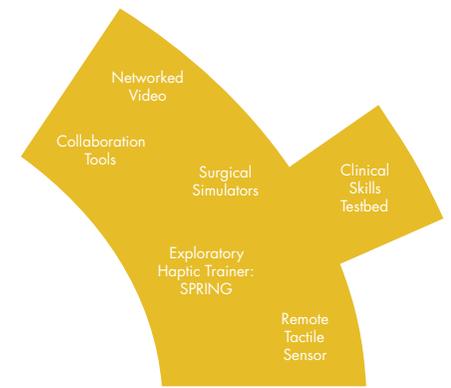
Networked Learning Events



- Two major laparoscopic surgery master classes were held between Stanford and CSIRO, Australia, using high-resolution stereo video and multi-user 3D models



Networked Learning Events



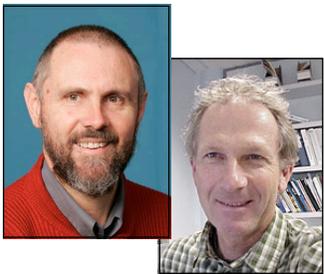
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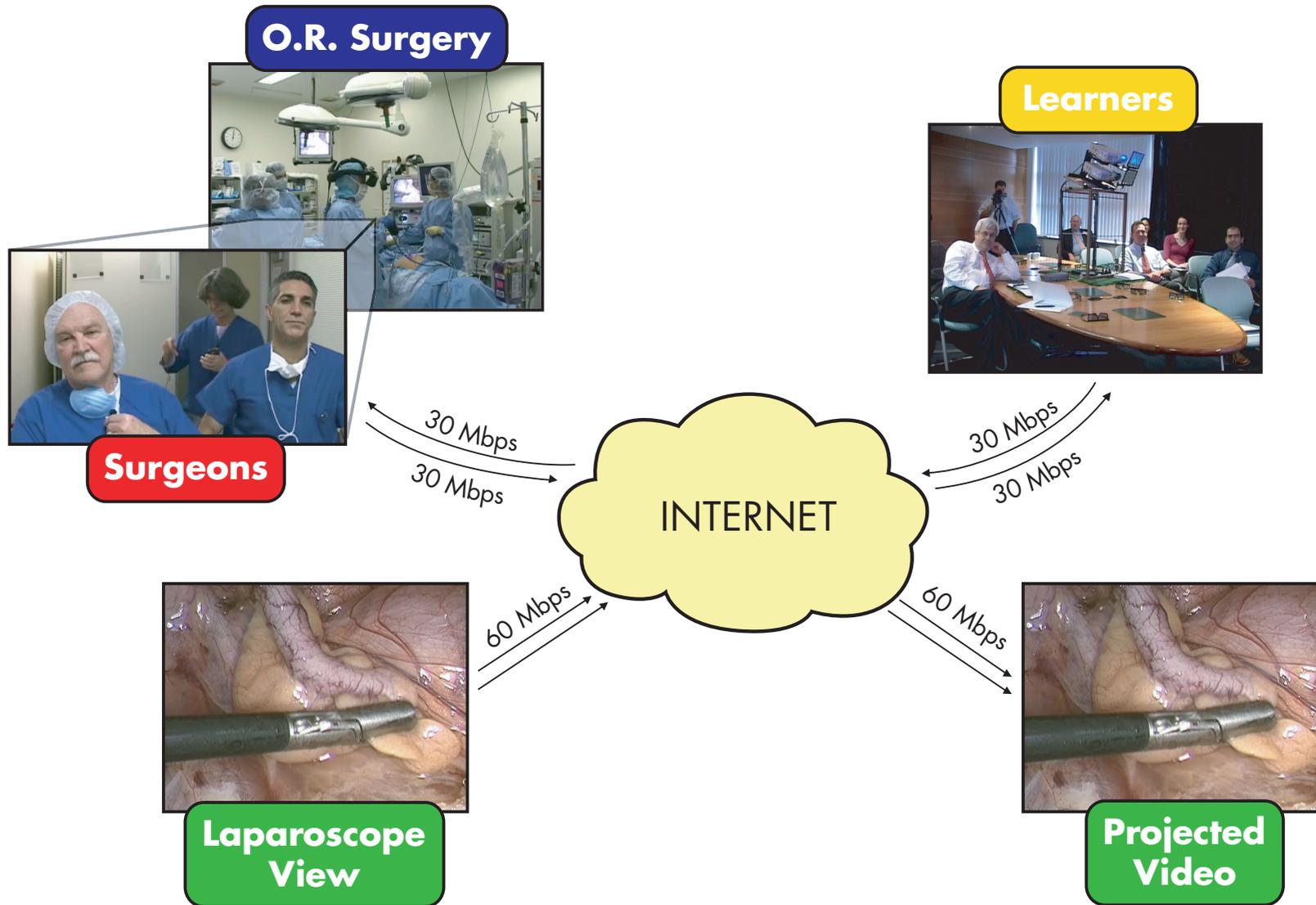
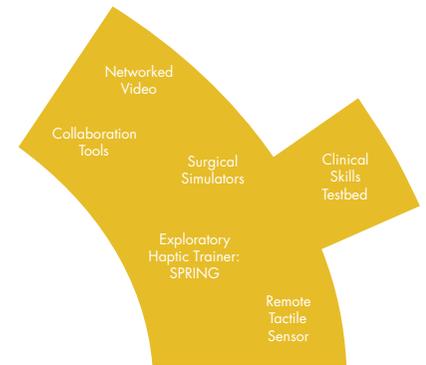
Networked Learning Events



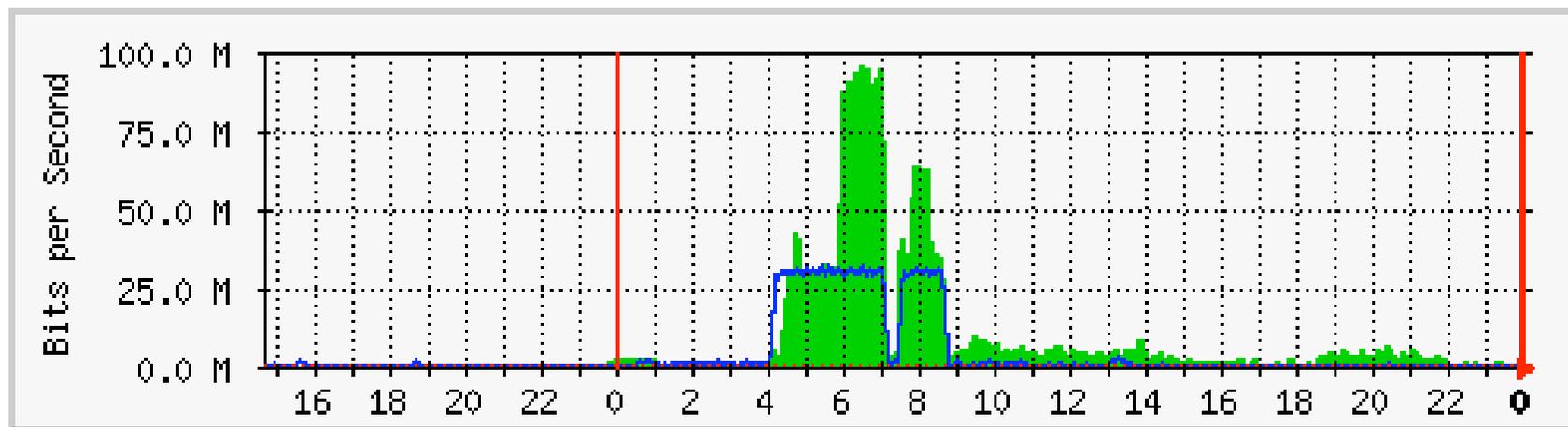
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Networked Learning Events



Networked Learning Events



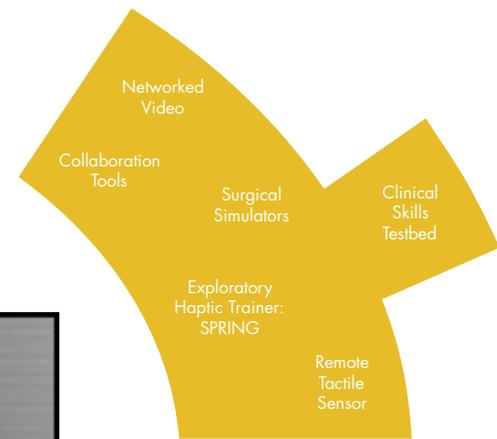
- Network traffic: Stanford to Australia (green)
 - two 30 Mbps streams of laparoscopy video (left & right eye)
 - one 30 Mbps videoconference stream
- Network traffic: Australia to Stanford (blue)
 - one 30 Mbps videoconference stream

SPRING



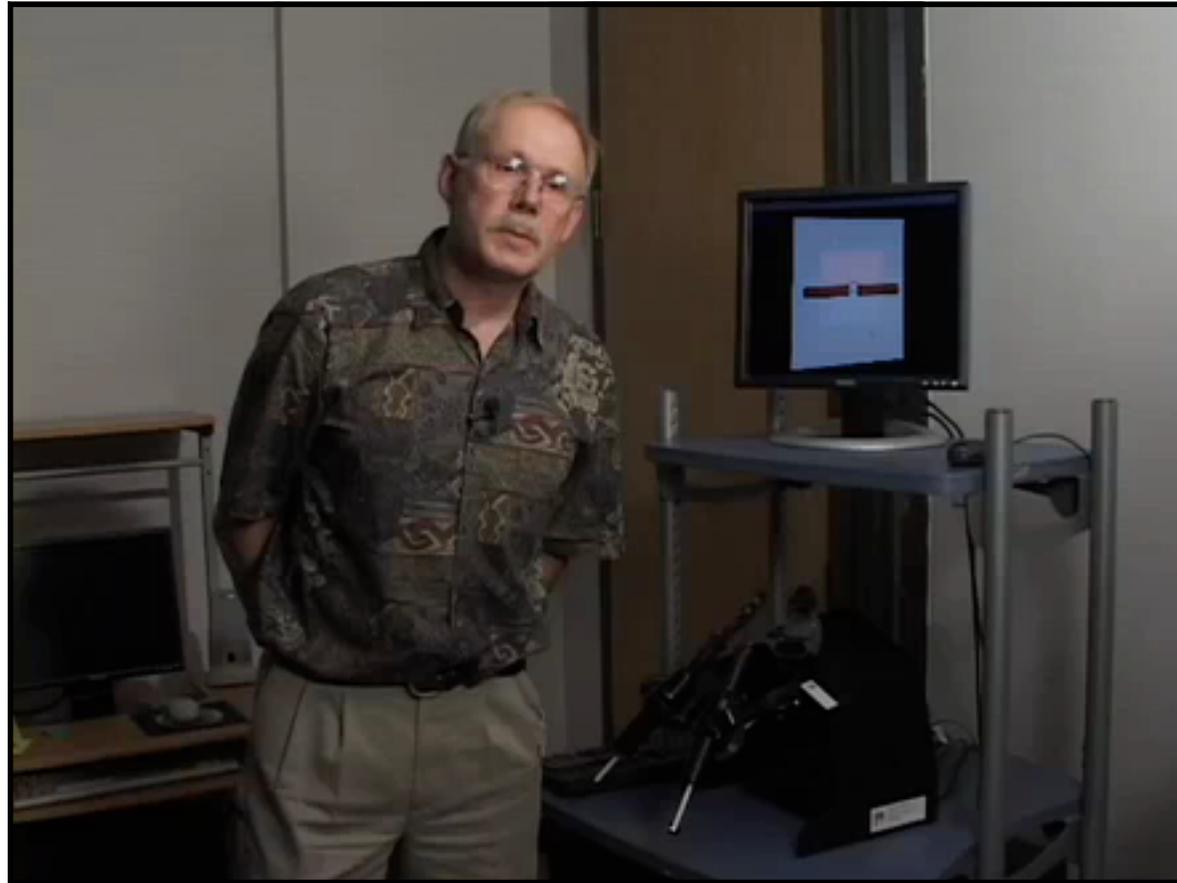
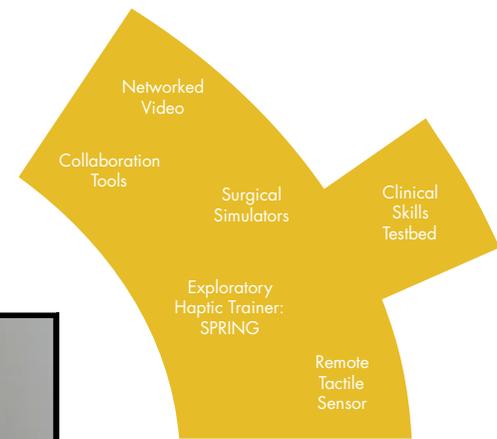
- Networked surgical simulation allows remote learners to “feel” the same haptic sensations as are felt by the hand of the teacher

SPRING



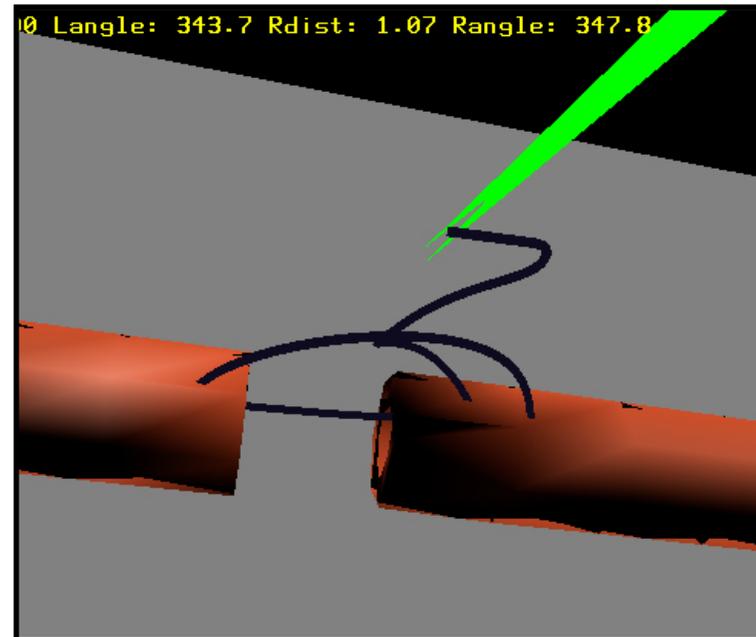
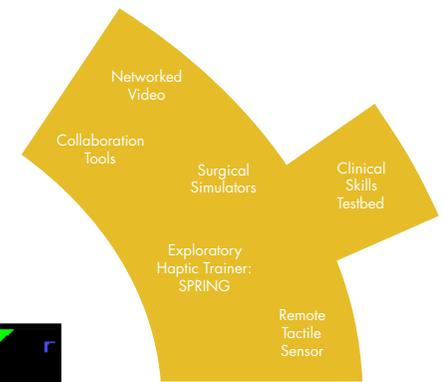
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SPRING



- Networked surgical simulation allows remote learners to “feel” the same haptic sensations as are felt by the hand of the teacher

SPRING



- SPRING networked simulation software, developed at Stanford, was re-engineered for performance and stability
- Used as base for simulator development and for experiments on haptic perception

SPRING



- SPRING has been disseminated globally as Open Source

SPRING



SUTURING TRAINER

View Intro

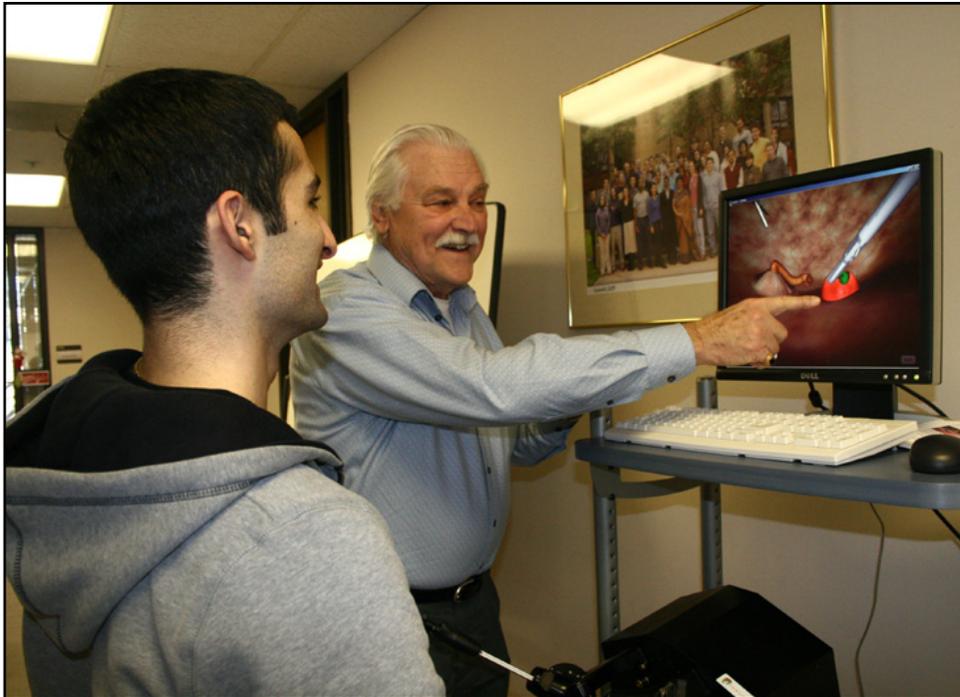
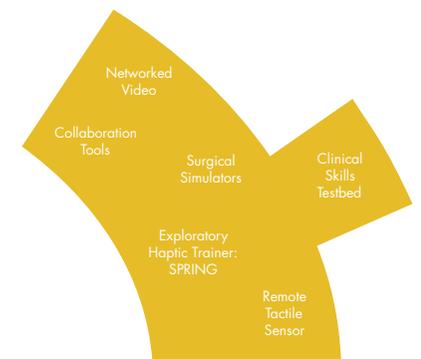
Login: **GO**

Credits:
Dhruv Garg; Rachel Fong; Michael Fagan; Madeleine Lemyre, MD; Craig Cornelius, PhD;
W LeRoy Heinrichs, MD, PhD; Parvati Dev, PhD

SUMMIT
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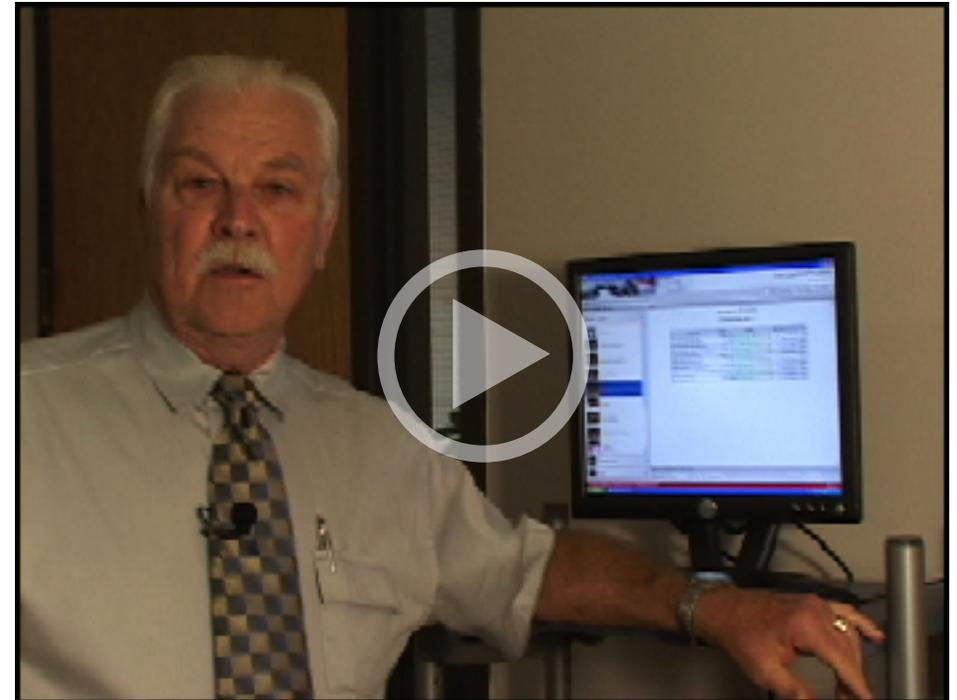
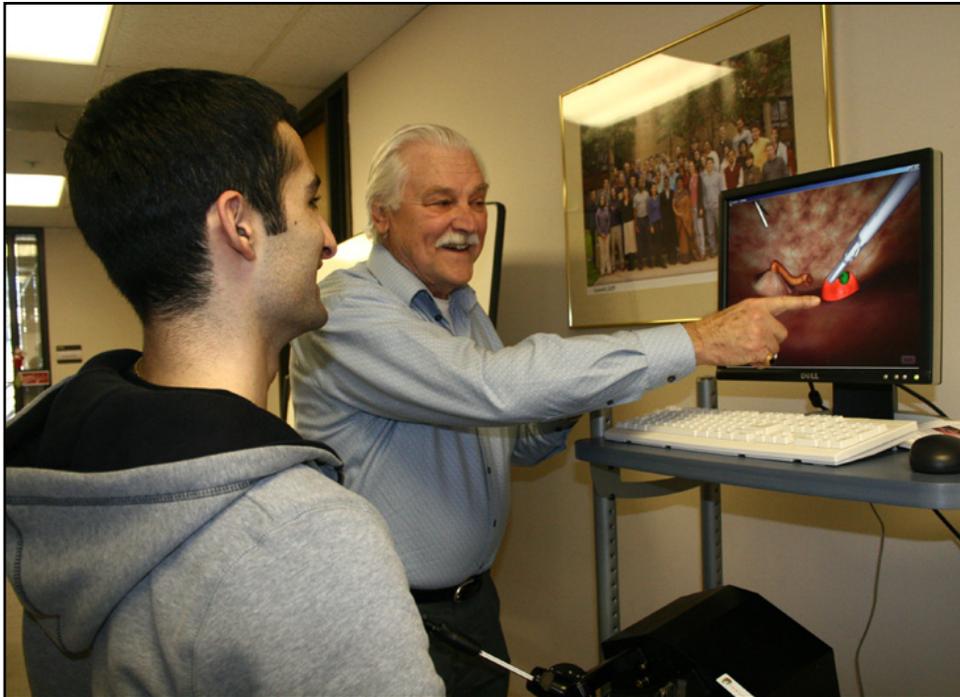
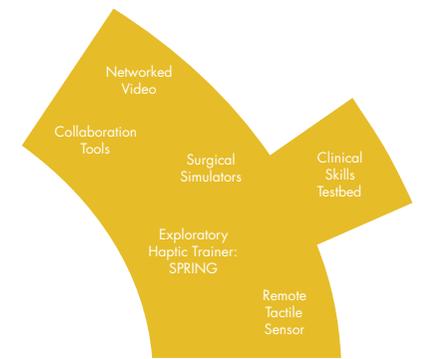
- SPRING has been used at Stanford, Hawaii, Arizona & other sites to develop experimental surgical simulations

Simulator Performance Metrics



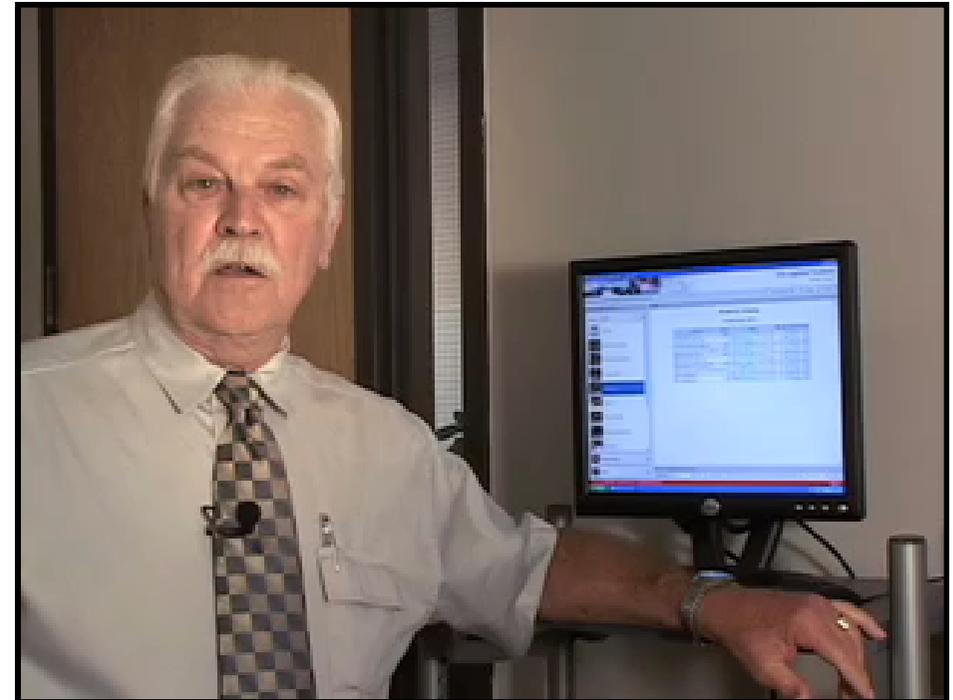
- Creating a statistical tool for evaluating performance scores for *Criterion-Based Training* with networked simulators

Simulator Performance Metrics



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Simulator Performance Metrics

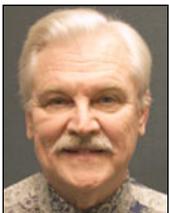
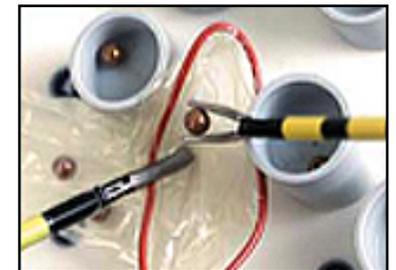
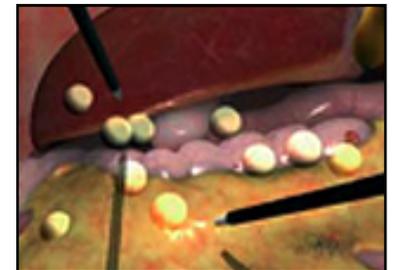
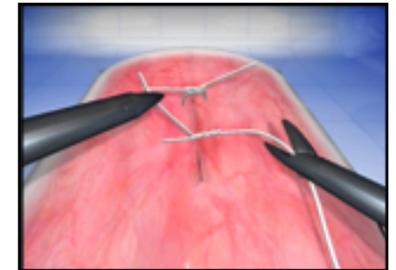


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Simulator Performance Metrics



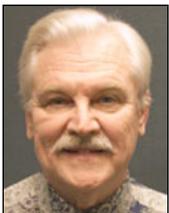
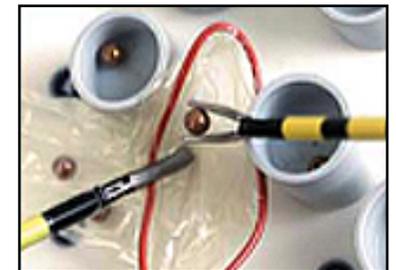
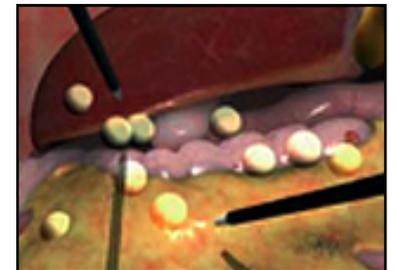
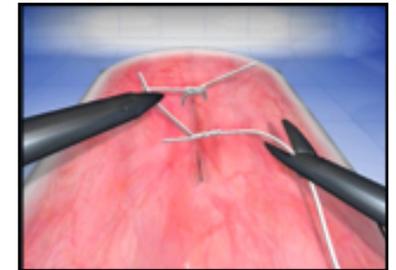
- Simulators used
 - Lap Mentor (Simbionix)
 - LapSim (Surgical Science AB)
 - LTS2000 ISM60 (RealSim)
 - ProMIS (Haptica)
 - SurgicalSIM (METI)
- Sample list of tasks
 - camera navigation
 - grasping and placing
 - clipping & cutting
 - suturing/knot tying
 - dissection/excision



Simulator Performance Metrics



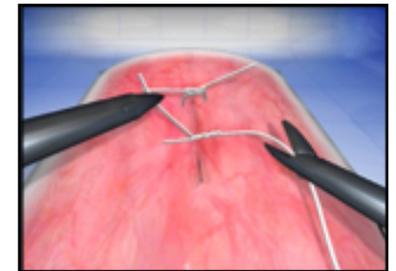
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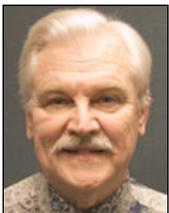
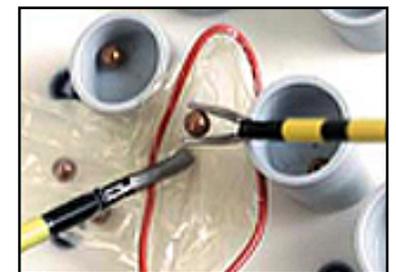
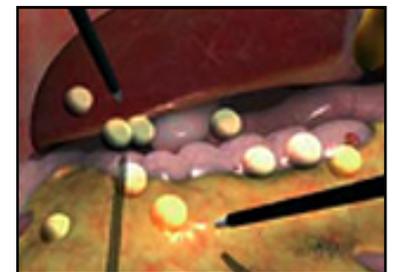
Simulator Performance Metrics



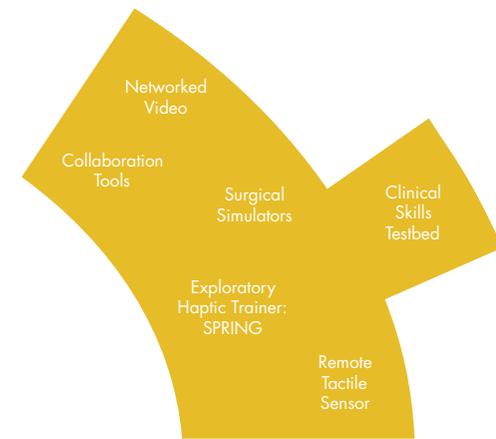
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Simulator Performance Metrics

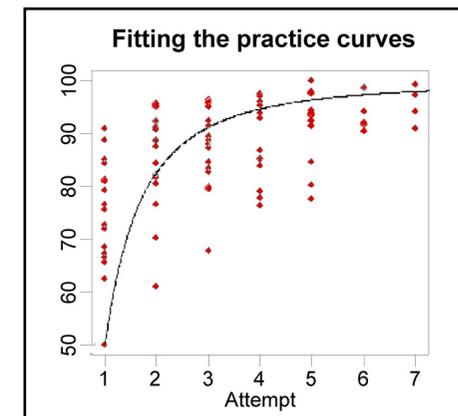


- Performance data collected with 17 surgeons on 26 tasks with 4–7 attempts on each task
- Proficiency score developed per task
 - weighted sum of all measures in task
 - weights adjusted using linear regression so that proficiency scores define a reasonable “practice curve”

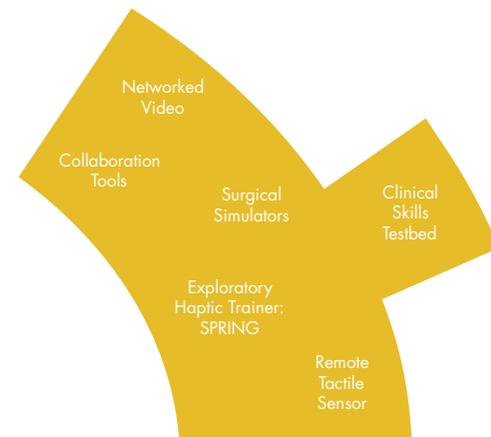
- A sample proficiency score for one task (LapSim camera navigation)

Proficiency = 112.52

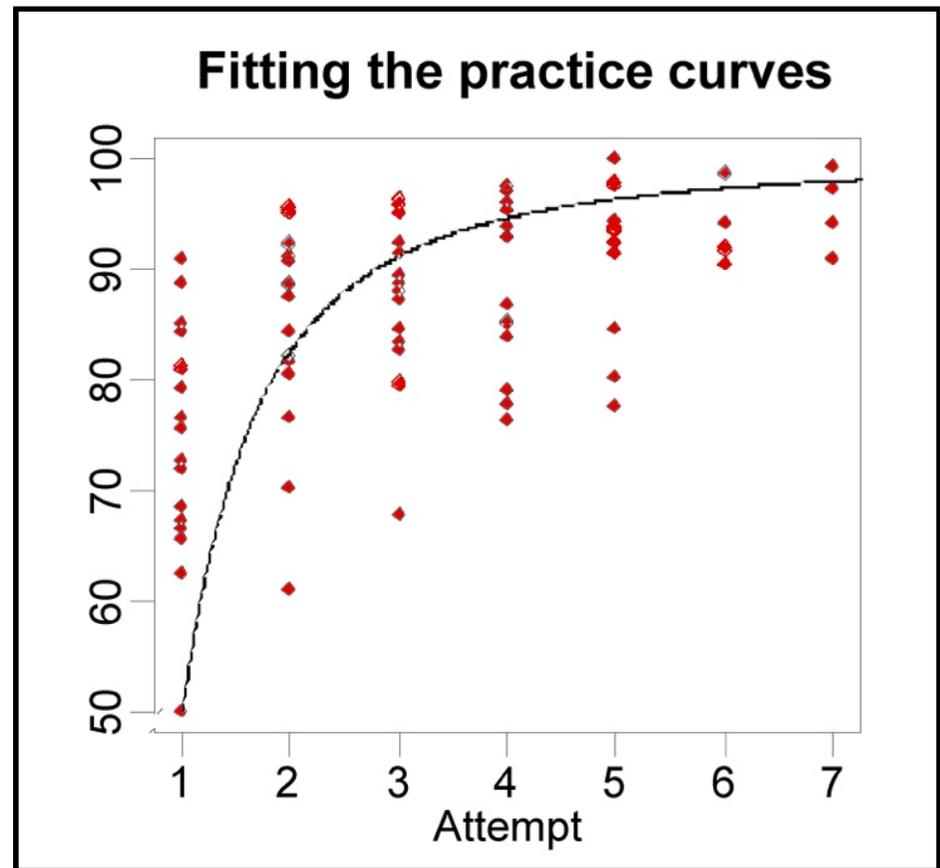
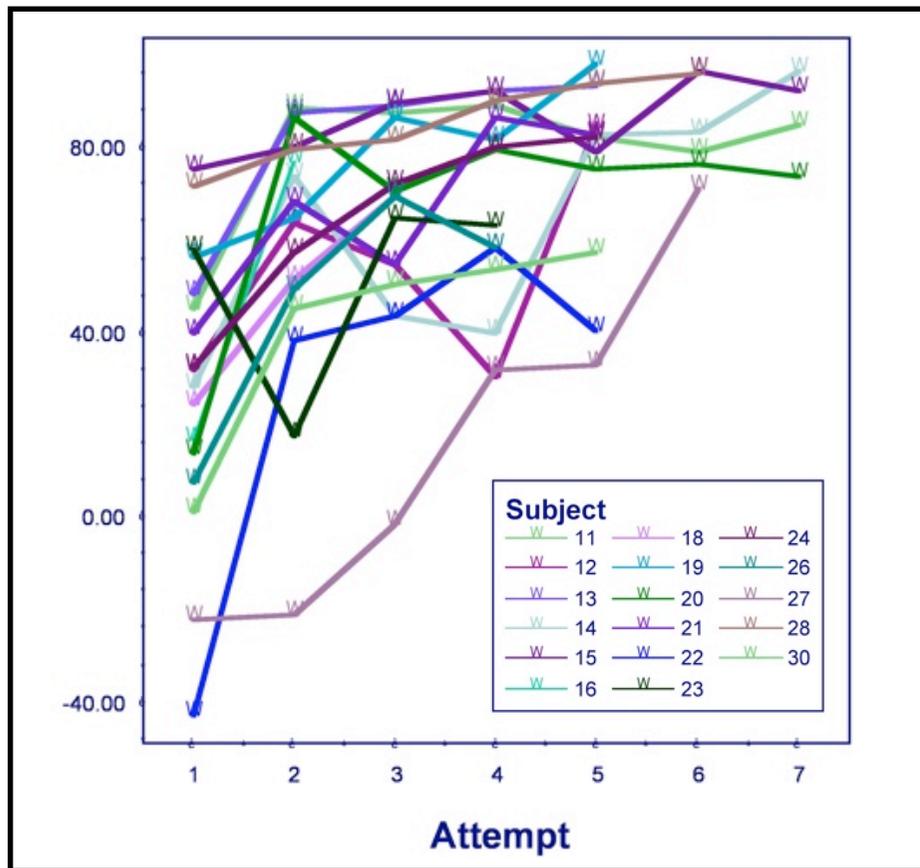
- $-3.72 \times \text{Path Length}$
- $-0.36 \times \text{Total Time}$
- $-0.10 \times \text{Drift}$
- $-1.82 \times \text{Tissue Damage}$



Simulator Performance Metrics



- Practice curves for surgeons on the LapSim camera navigation task demonstrate learning curves that led to selection of 4th attempt data

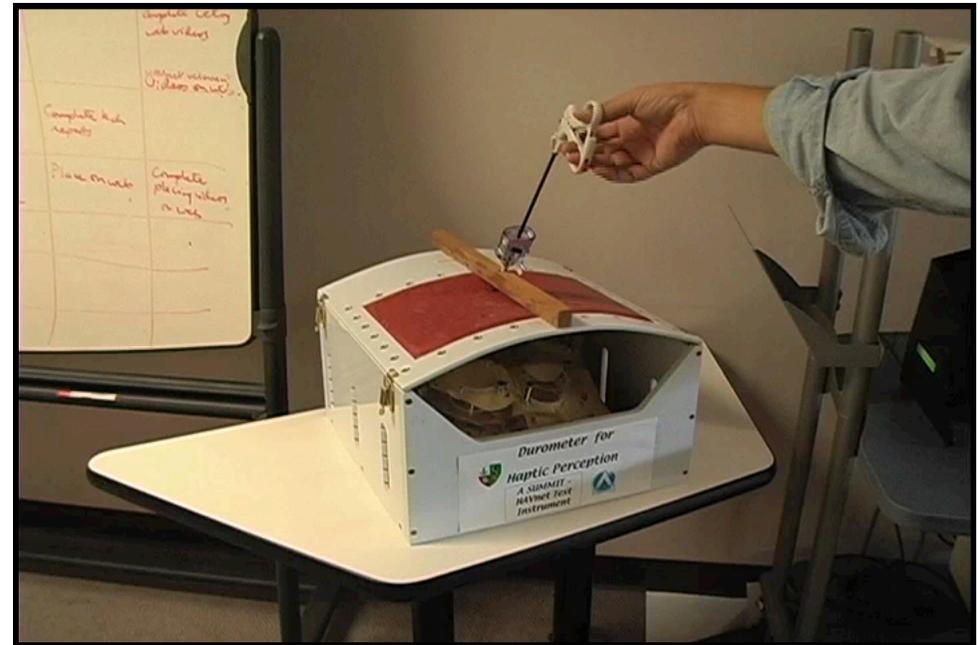
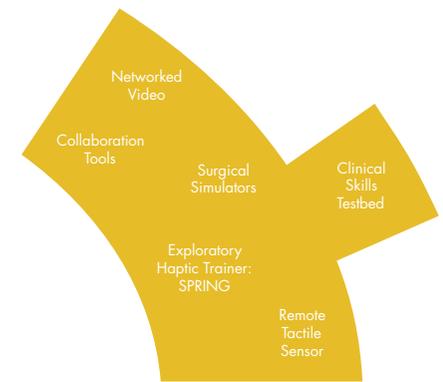


Haptics Experiments



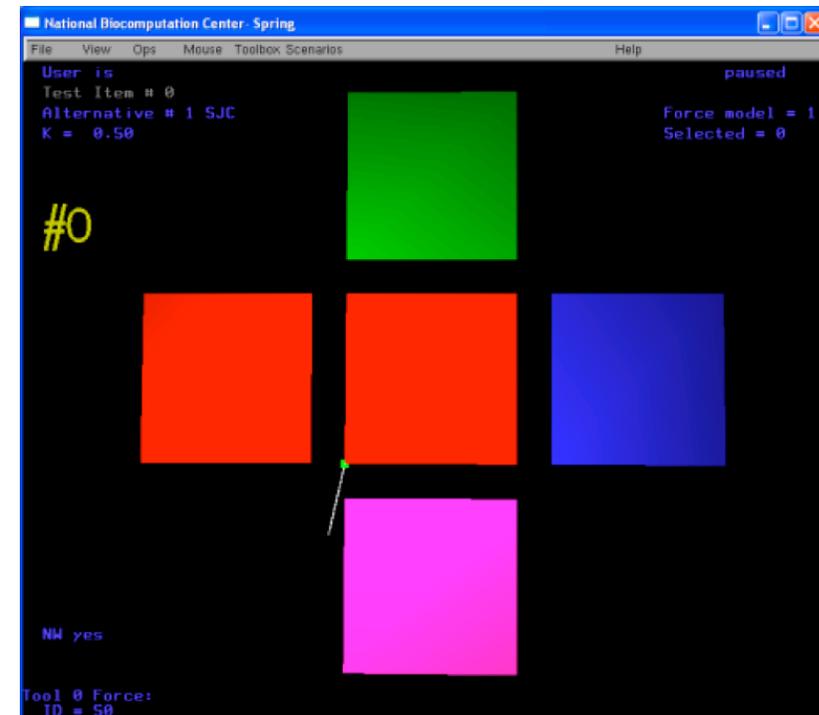
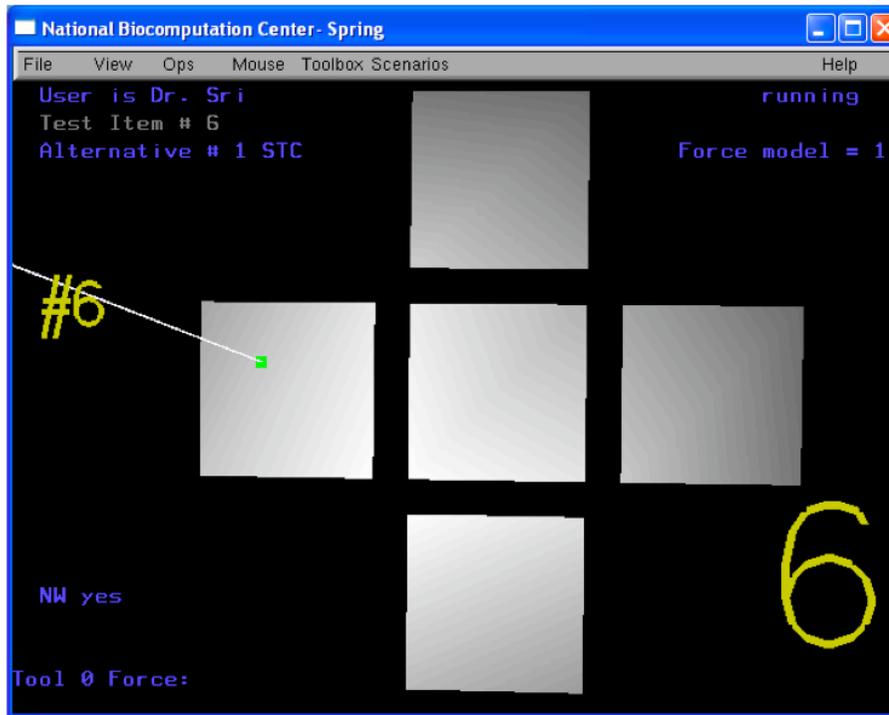
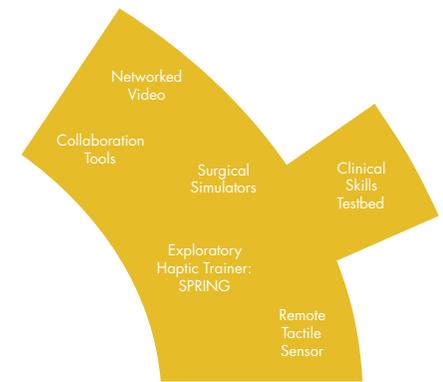
- 10 6x6" sheets with thickness from 0.004-0.050"
- Subjects are able to detect differences and to order in sequence of thickness

Haptics Experiments



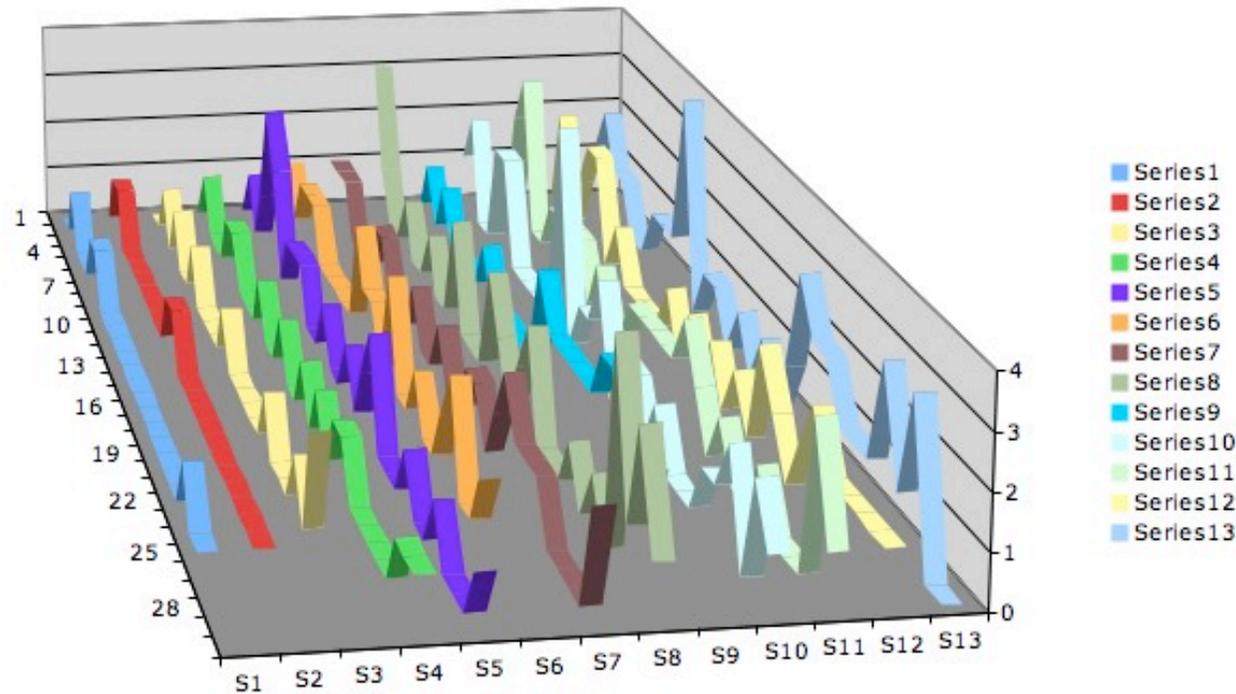
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Perceiving Differences in Elasticity



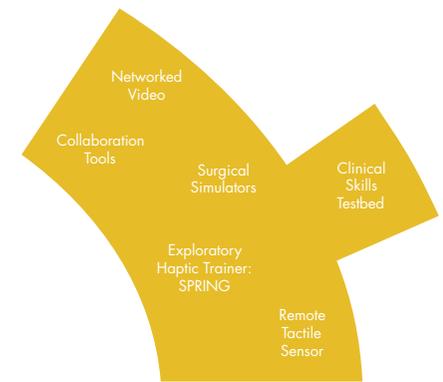
- Subjects have difficulty comparing elasticity between virtual membranes

Perceiving Differences in Elasticity



- Of 13 subjects, only 2 detected similar pairs accurately
 - In a range of experiments, with various models of elasticity, difficulty in detecting similar pairs remained

Perceiving Differences in Force



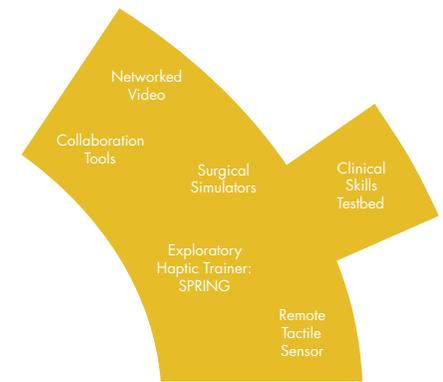
- Are these two forces the same or different?

Perceiving Differences in Force



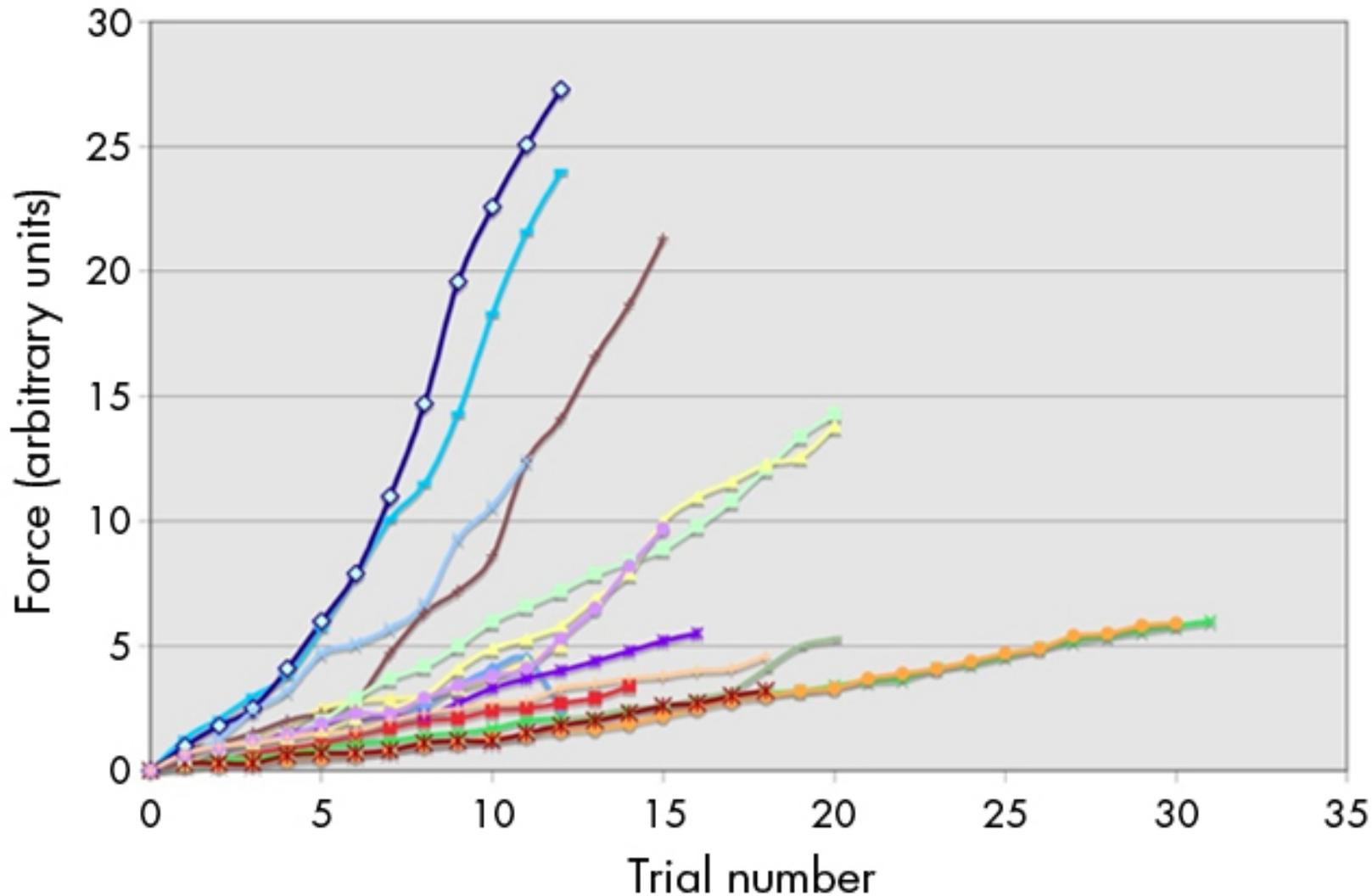
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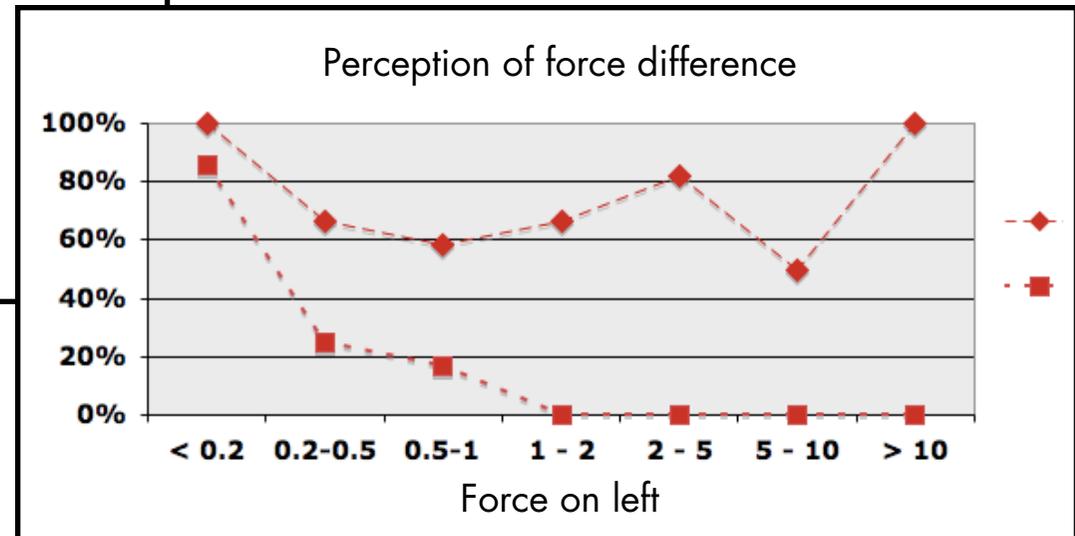
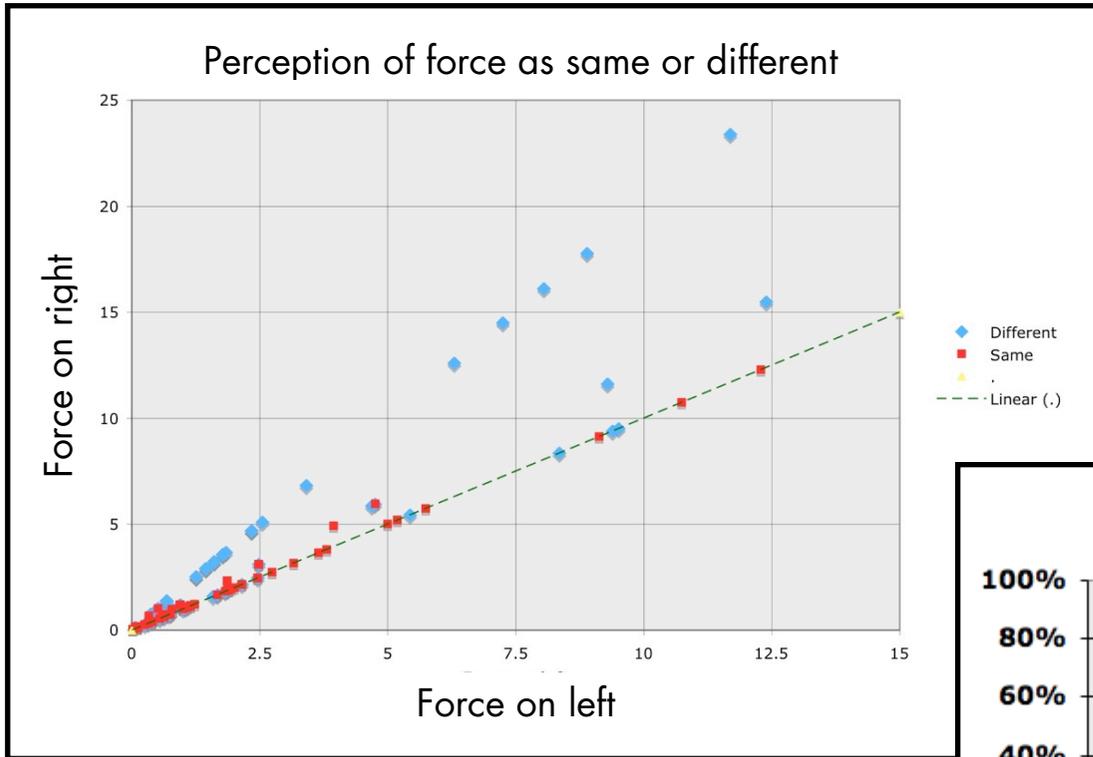
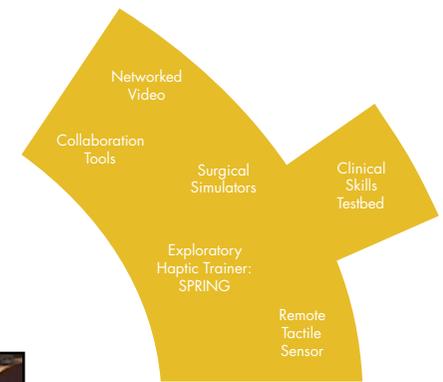


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Perceiving Differences in Force

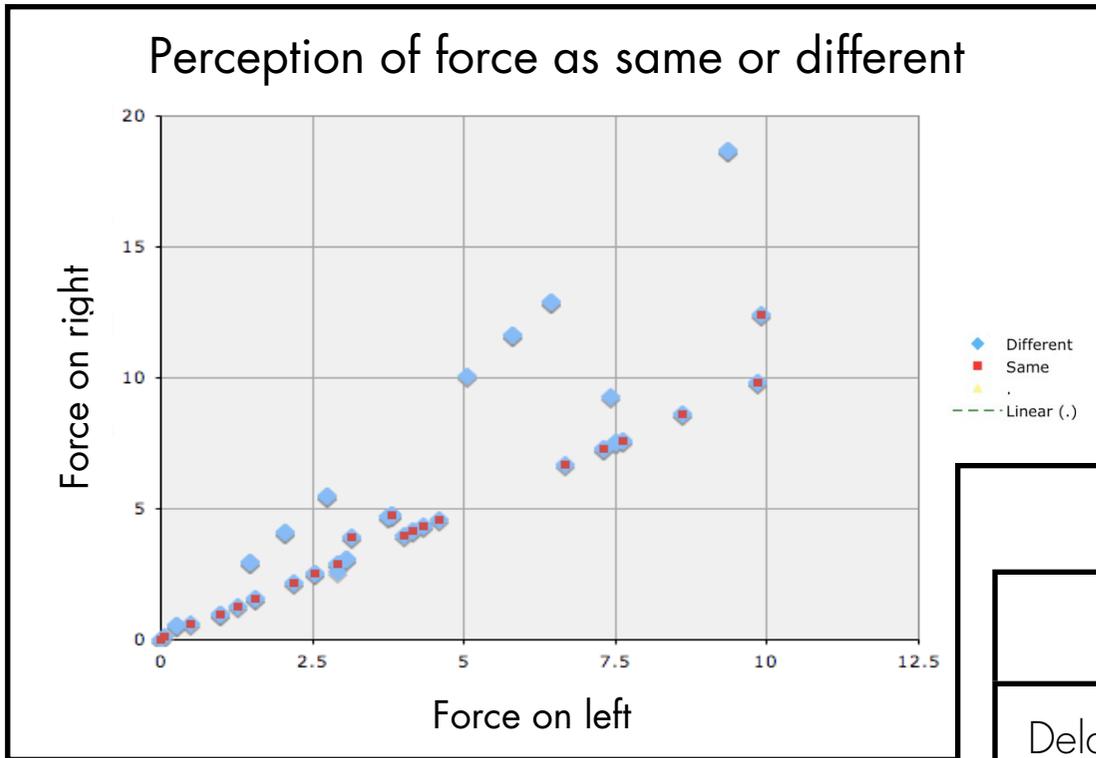


Perceiving Differences in Force



- 4 subjects; 142 trials

Perceiving Differences in Force



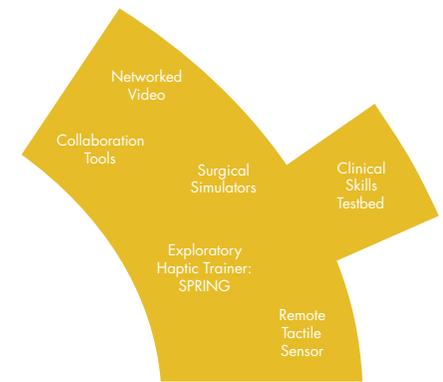
Forces are perceived as same

	Forces are same	Forces are different
Delay 0–20ms	66%	17%
Delay > 50ms	2%	0%

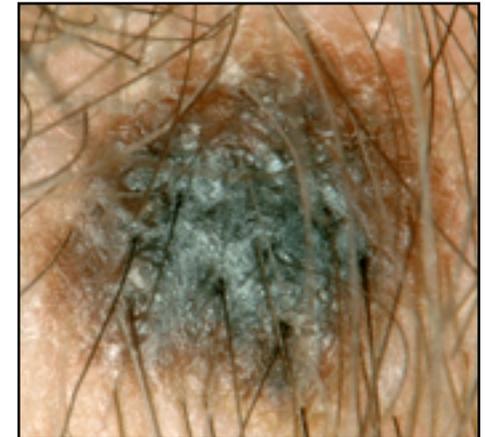
Force on left

- Subjects interpret haptics with network delay as a difference in force

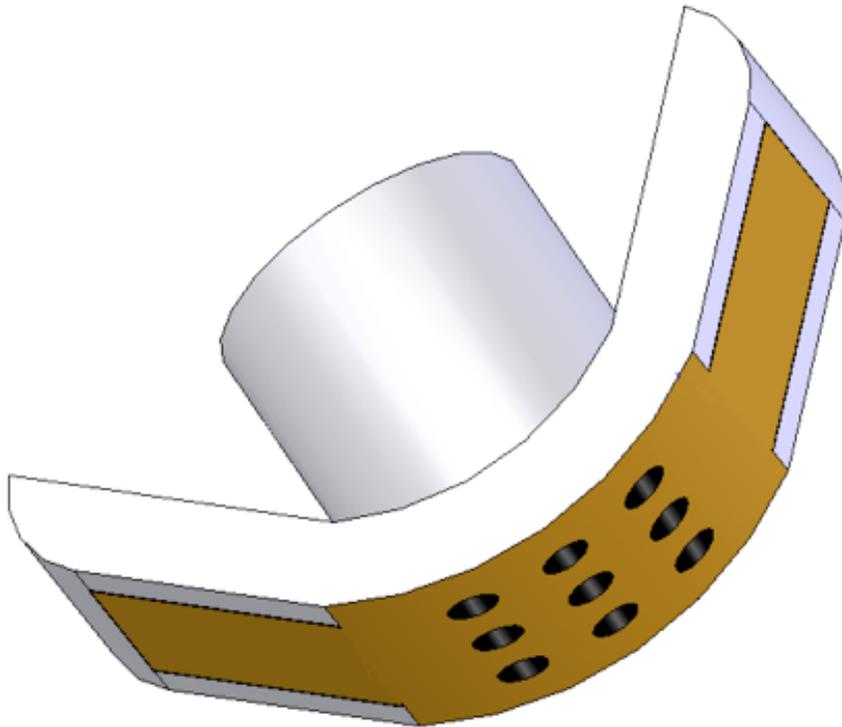
Remote Tactile Sensor: Objectives



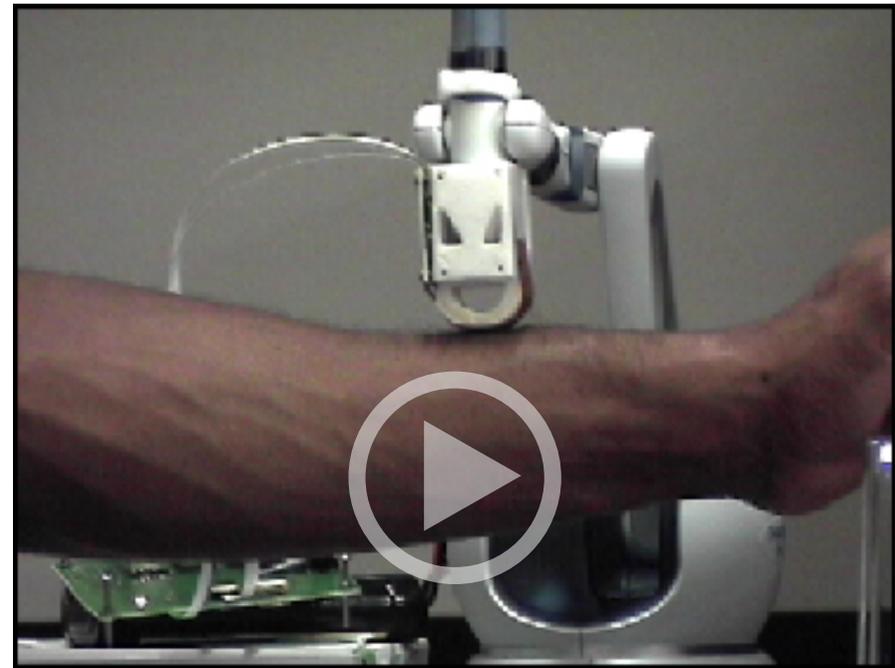
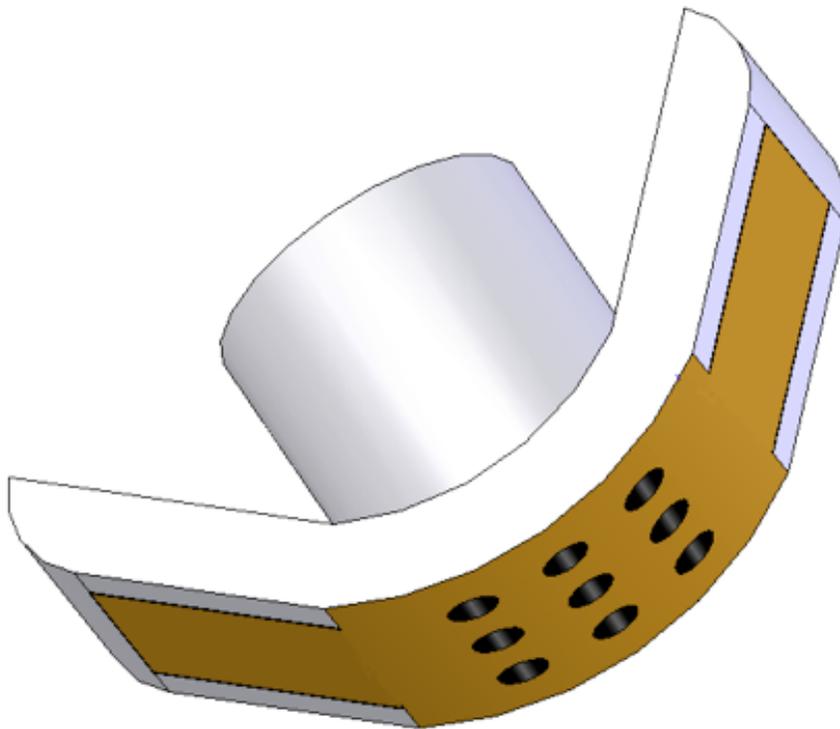
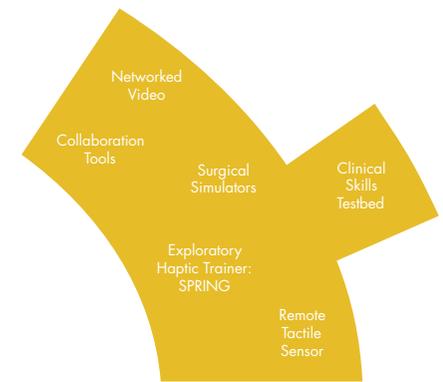
- Skin cancer is the most prevalent form of cancer in light-skinned populations
 - Objective is to assemble a system for remote diagnosis and remote instruction
 - Dermatological diagnosis requires high-definition video and palpation
 - Use haptic robotics for palpation
 - Test a latency sensitive application using haptics over network



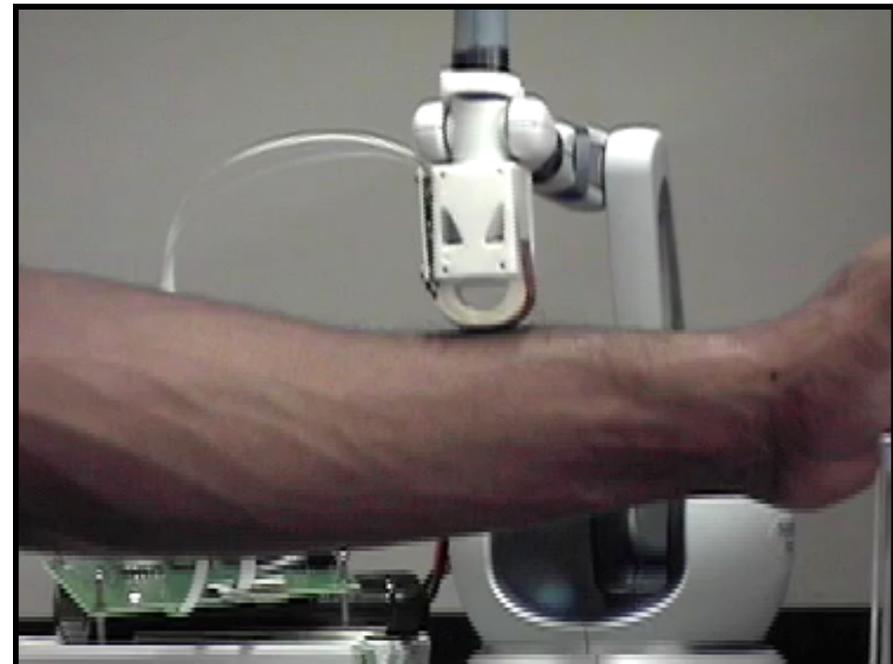
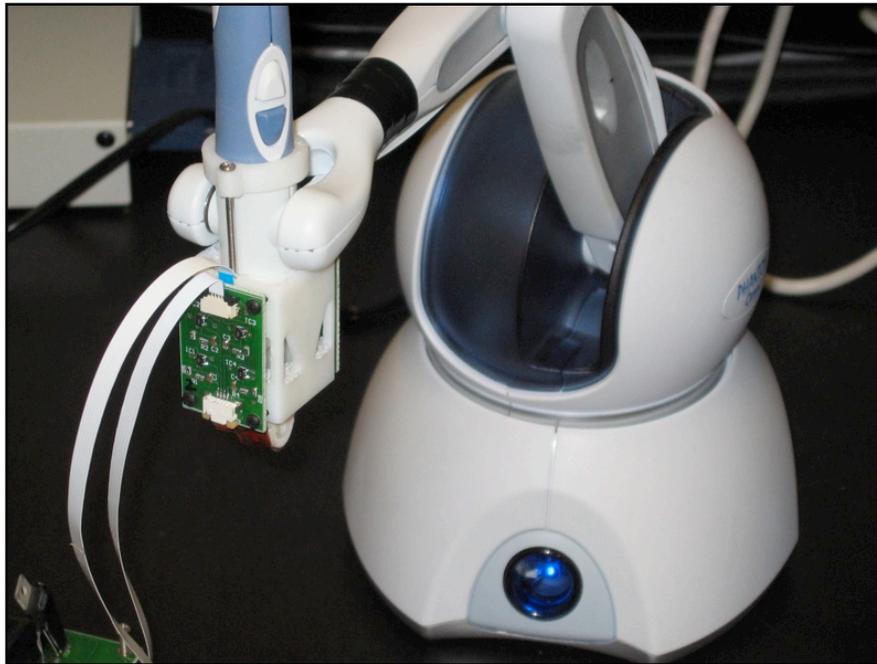
Remote Tactile Sensor: Operation



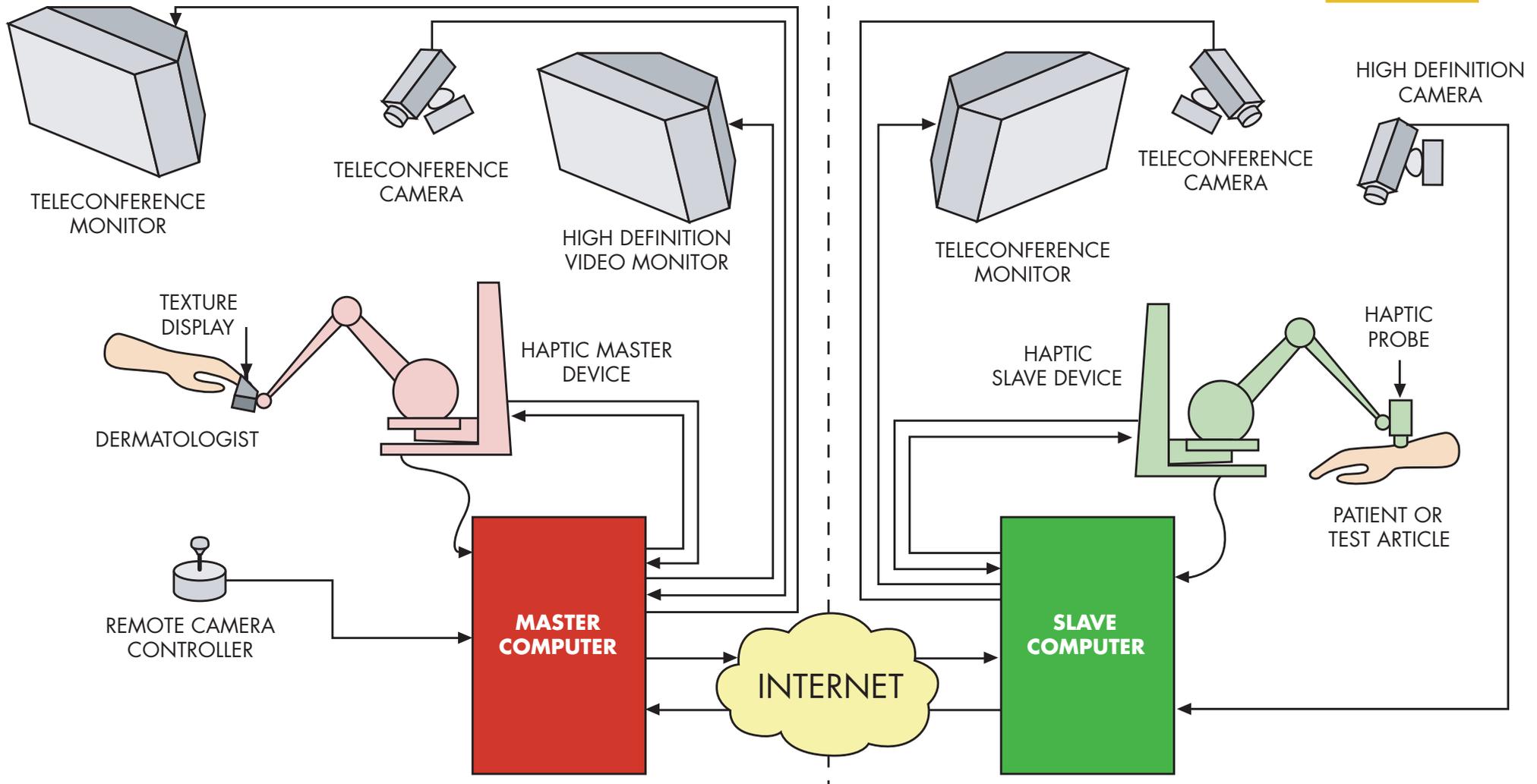
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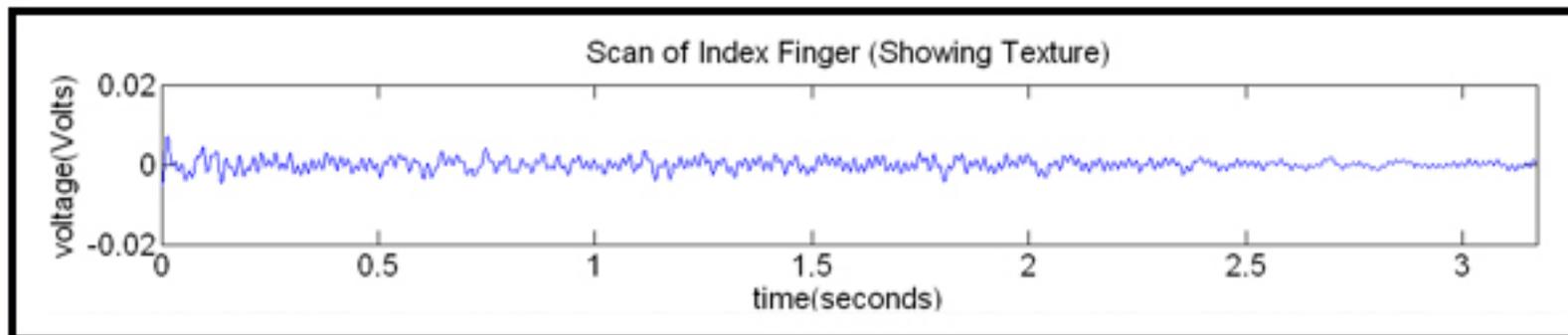
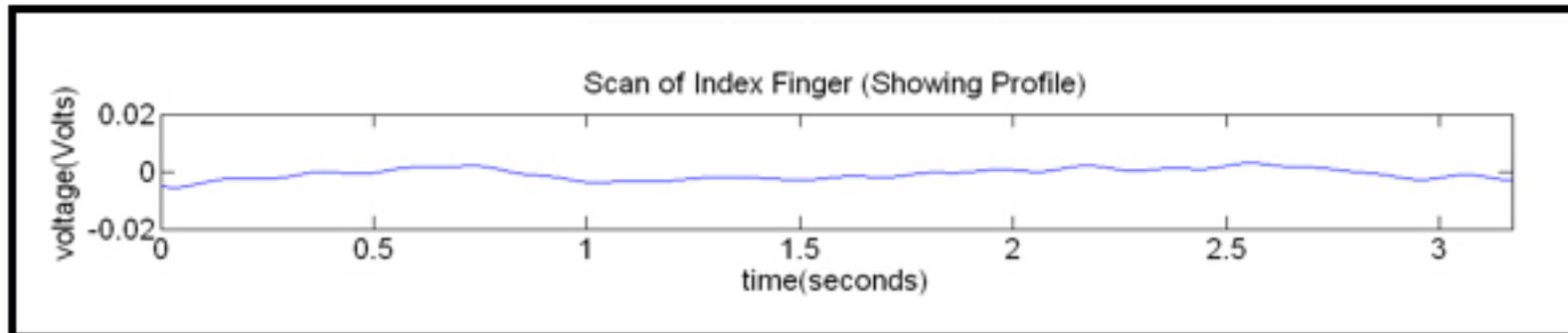
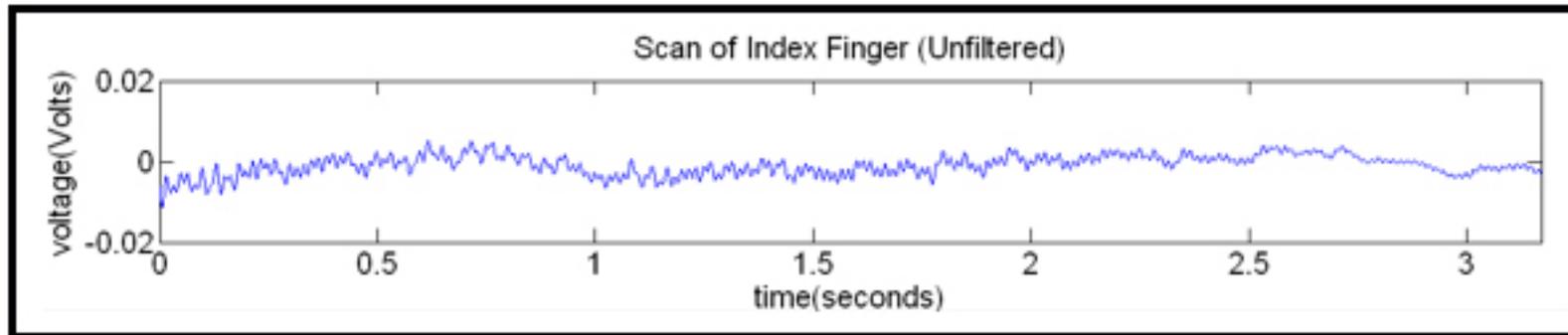
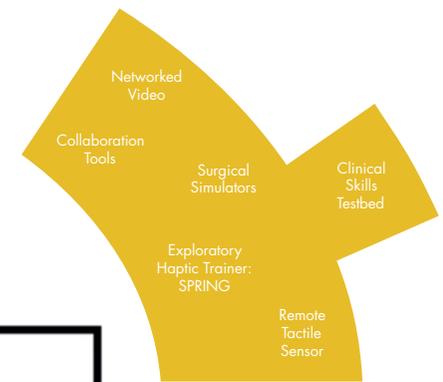
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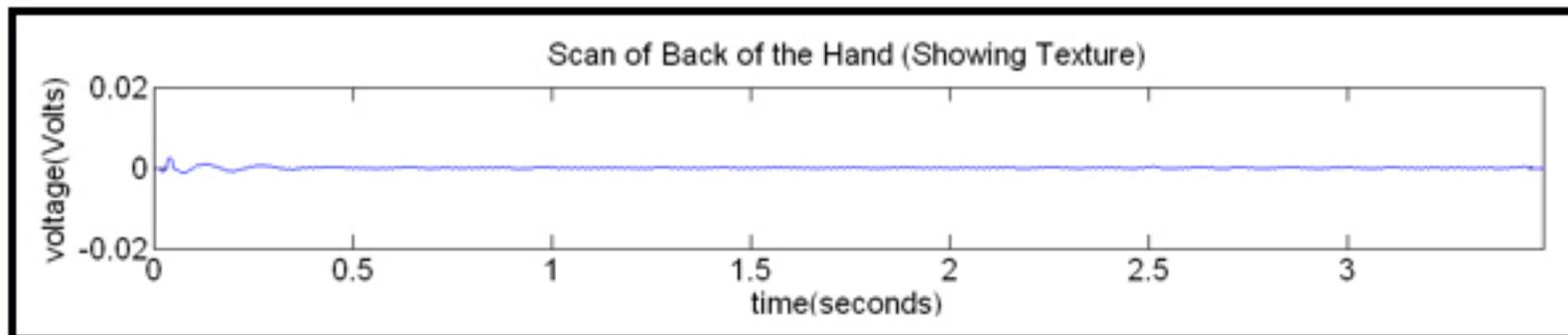
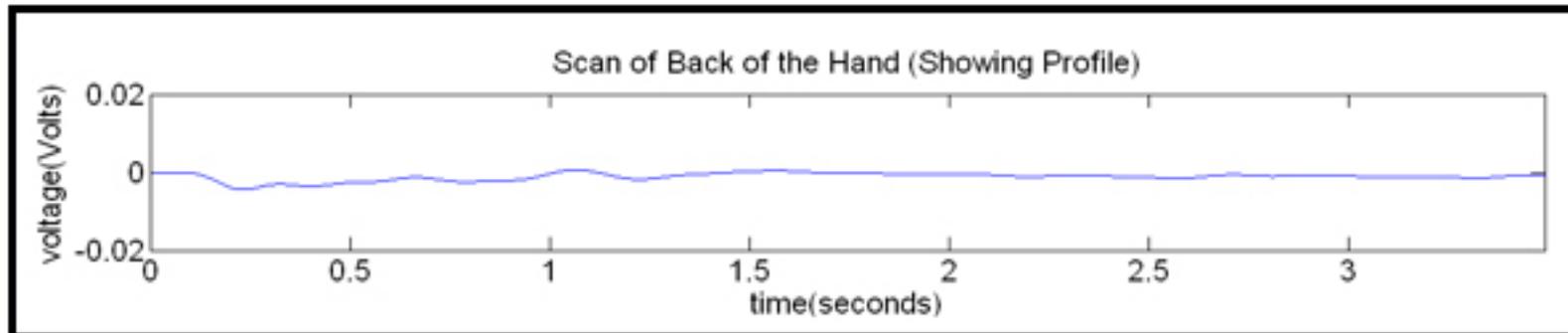
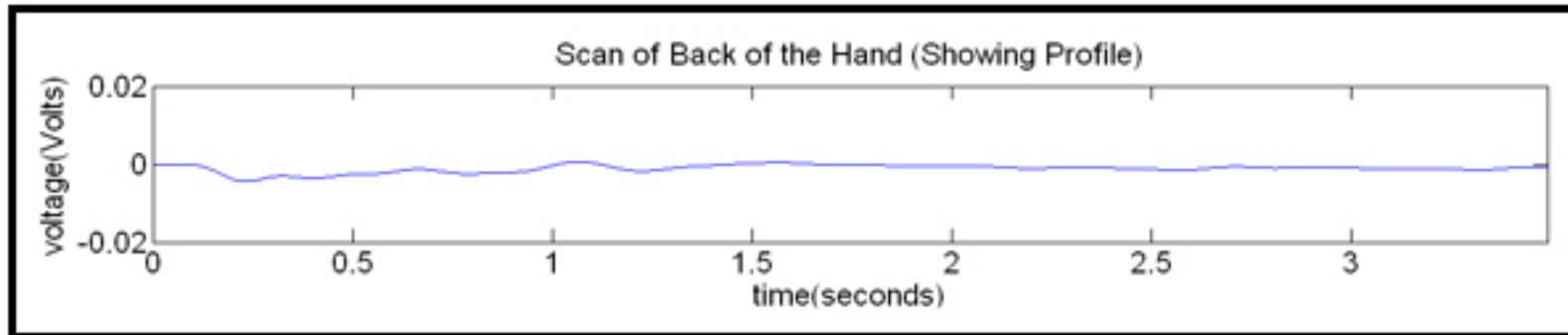
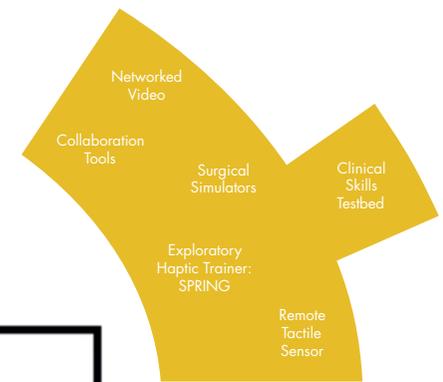
Remote Tactile Sensor: System



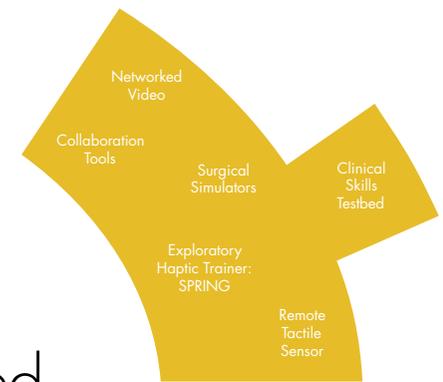
Remote Tactile Sensor: Data



Remote Tactile Sensor: Data

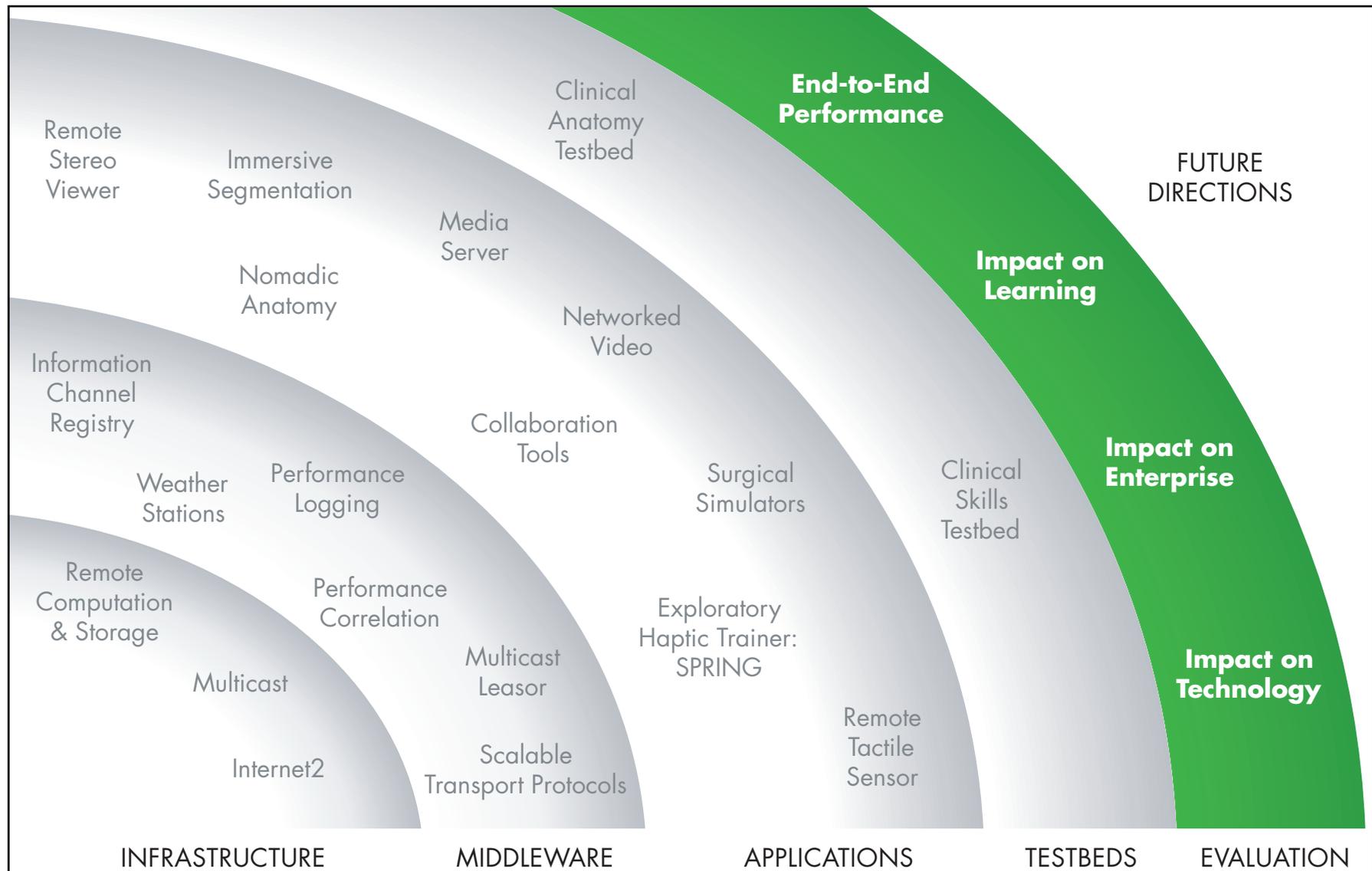


Remote Tactile Sensor: Summary

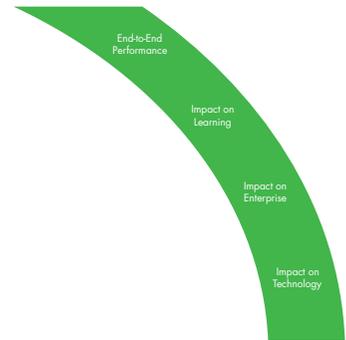


- Transmission in digital form over the internet is assumed
 - Bandwidth requirements for haptic data are modest: a few Mb/s
 - Significant latency is observed due to speed of light delay, switching, compression/decompression etc.
 - leads to stability problems
 - Need special sensor to provide both texture and profile data
 - Need special display for texture data
 - Continuing research

Evaluation



End-to-End Performance



Anatomy Portal for Digital Resources
<http://ianatomy.stanford.edu/>

SUMMIT **iAnatomy**
 Digital Anatomy Network Channel

Northern Ontario School of Medicine & SUMMIT received a 2007 Innovations in Networking Award for High Performance Network Research in Education from CENOCI
[Read more!](#)

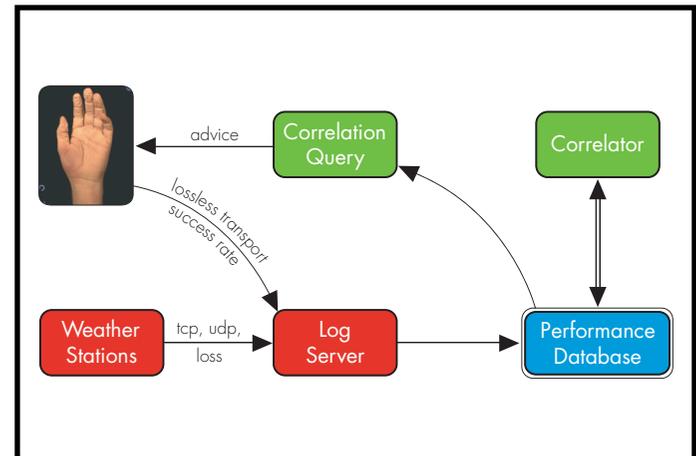
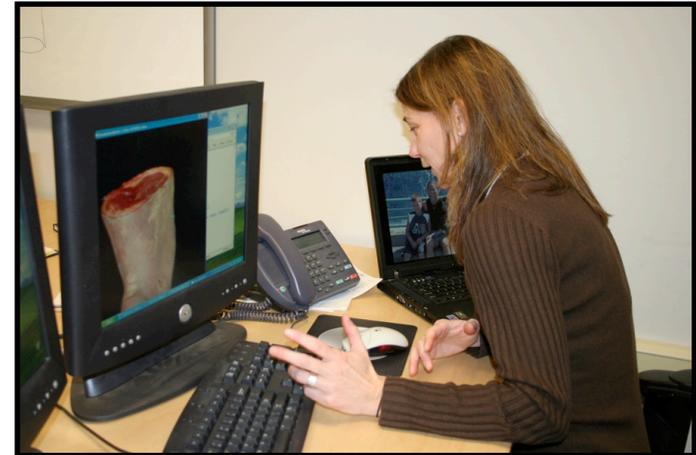
The **Bassett** collection consists of 1500 high resolution stereoscopic images, prepared in the 50's by a Stanford anatomist, Dr. David Bassett and William Gruber, the inventor of the Viewmaster.

Getting Started Guides
 Use NOSM Teaching Files
 Search the Bassett collection
 Use Remote Stereo Viewer (RSV)
 - Self Study
 - Groups

2006 - 2007 Academic Year - Anatomy Stereo Image Sets
 Note: To view these stereo image sets, you must have the application: Remote Stereo Viewer.

Stanford SOM CCSR Stereo Viewing Directions	Northern Ontario School of Medicine (NOSM) - Module 106 (MSK)		
Lung and Pleurae	Skull: Bones & Muscles	Spine: Bones & Muscles	Ribcage: Bones & Muscles
Thorax	Skull: Bones & Muscles with legend	Spine: Bones & Muscles with legend	Ribcage: Bones & Muscles with legend
	Upper Extremity: Bones & Muscles	Upper Extremity: Bones & Muscles with legend	Lab exam 1
	Lower Extremity: Bones & Muscles	Lower Extremity: Bones & Muscles with legend	Lab Exam 2 Lab Exam 3

<http://ianatomy.stanford.edu/index.html>



Impact on Learning

End-to-End
Performance

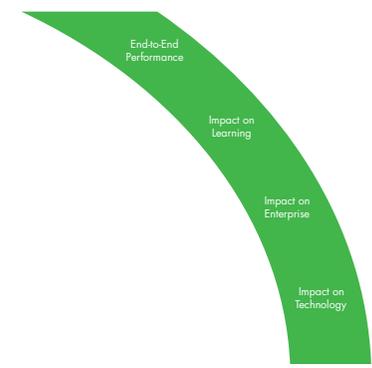
Impact on
Learning

Impact on
Enterprise

Impact on
Technology

- Access to remote rich-media resources, with powerful but simple interfaces, is critical in new learning environments
 - distributed medical school; global learning events
- Access to novel sensory channels will place demands on networks, computing, interfaces and transparency of access for new learning environments
 - haptic sensing of a remote skin lesion, or a master surgeon's movements
 - ability to position a virtual camera anywhere in a captured light field

Impact on Technology



- Transport protocols, performance monitoring, end-to-end performance
 - formation of Bulk Transport working group in Internet2 and definition of API for new protocol
 - sensitization of Internet2 community to technology to support collaboration, such as Multicast and real-time video collaboration in high resolution
- Simulation technology
 - release of SPRING networked simulation software to Open Source
 - workshop to bring together the surgical and development communities
- Collab Room
 - design of a collaboration-intensive learning space
 - multiple video and data streams transmitted and received

Impact on Enterprise

End-to-End
Performance

Impact on
Learning

Impact on
Enterprise

Impact on
Technology



Impact on Enterprise

End-to-End
Performance

Impact on
Learning

Impact on
Enterprise

Impact on
Technology



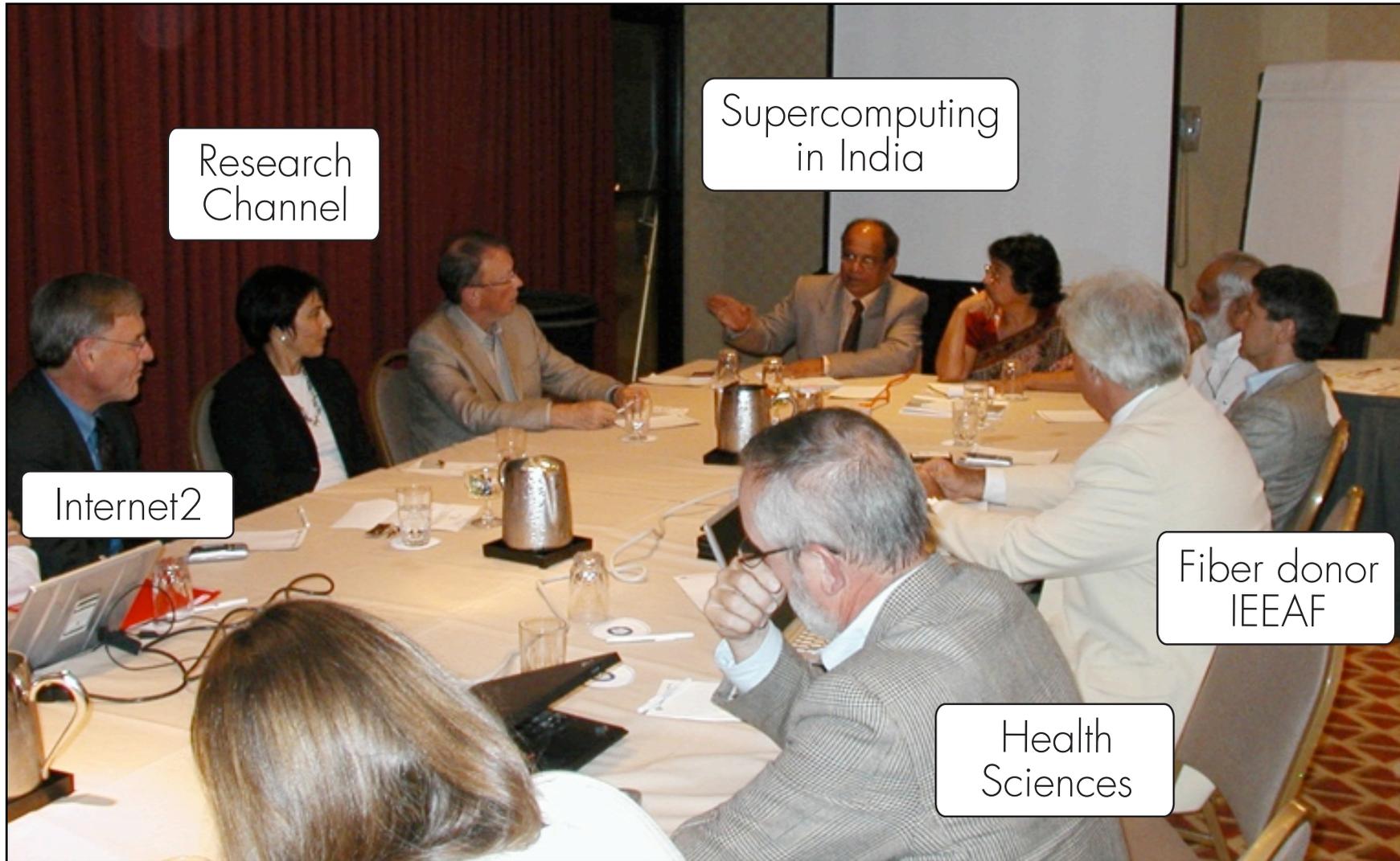
Impact on Enterprise

End-to-End
Performance

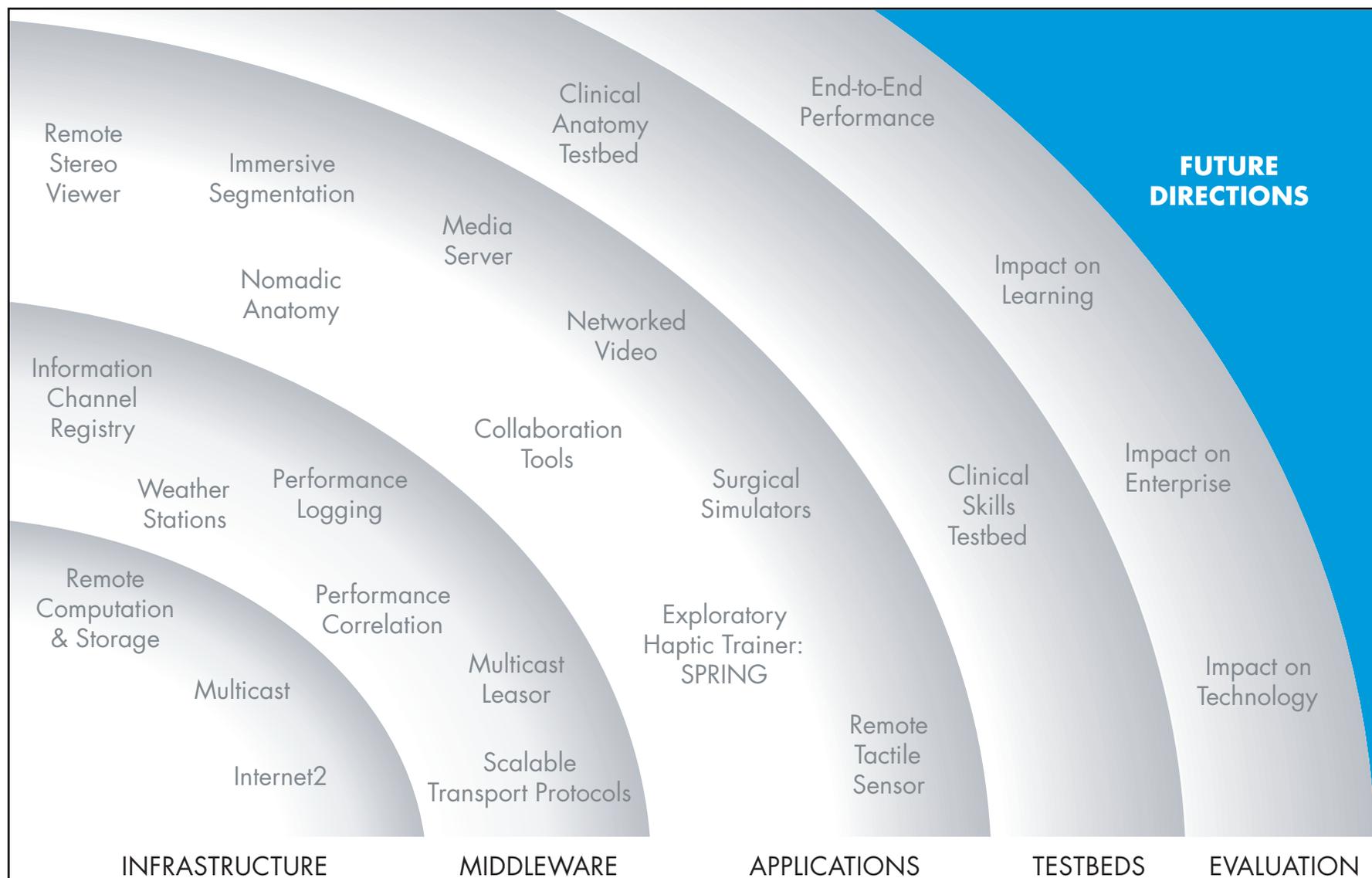
Impact on
Learning

Impact on
Enterprise

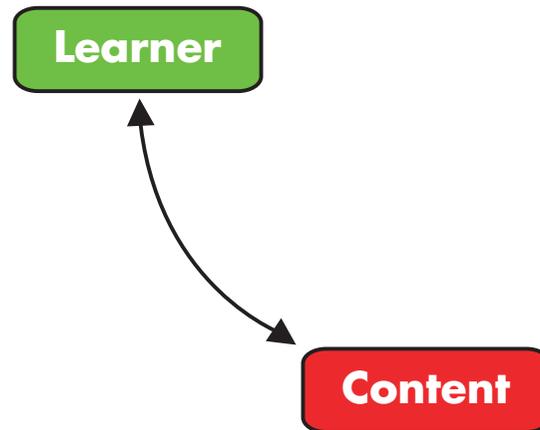
Impact on
Technology



Future Directions

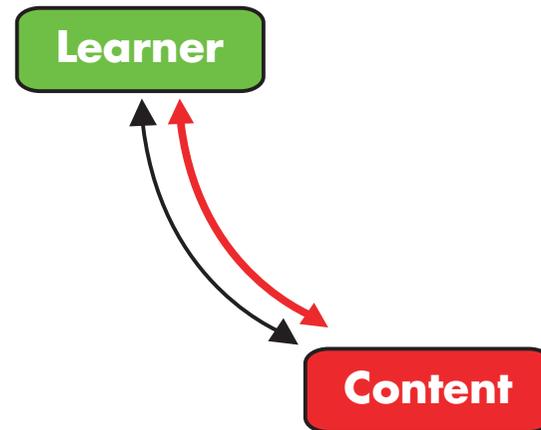


Future Directions



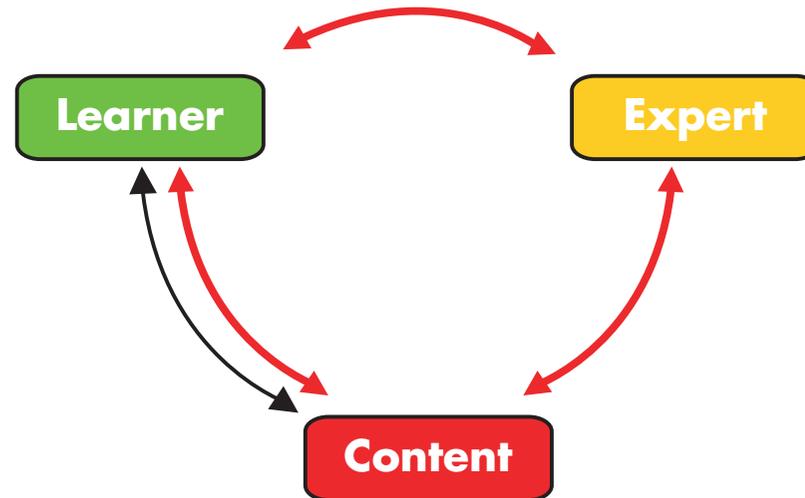
- Working with increasingly complex data brought together from multiple remote sites

Future Directions



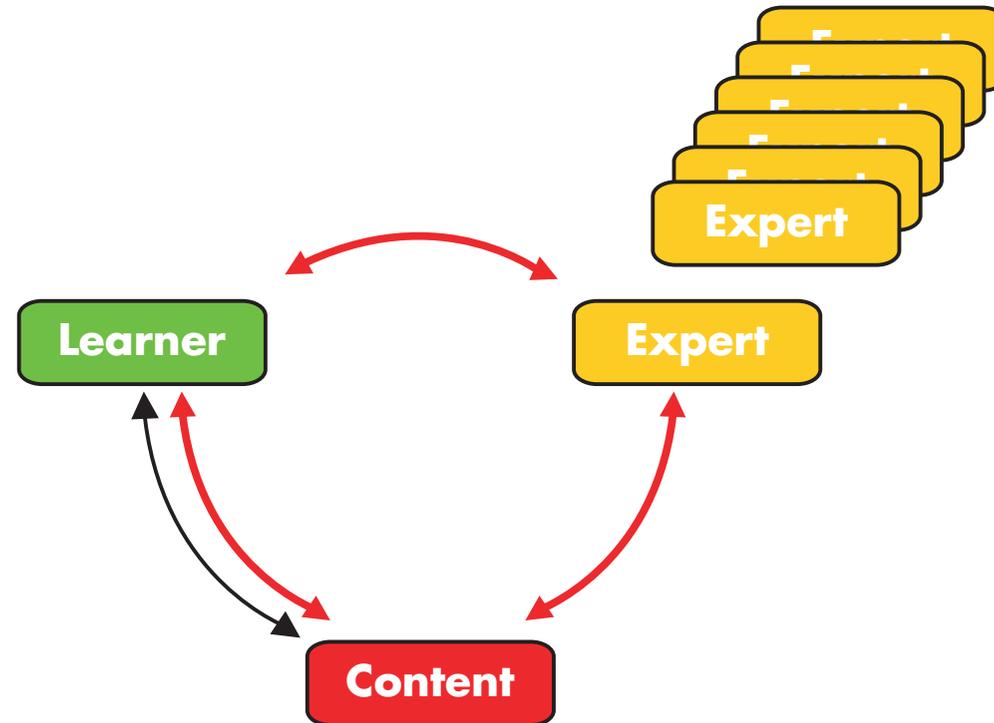
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Future Directions



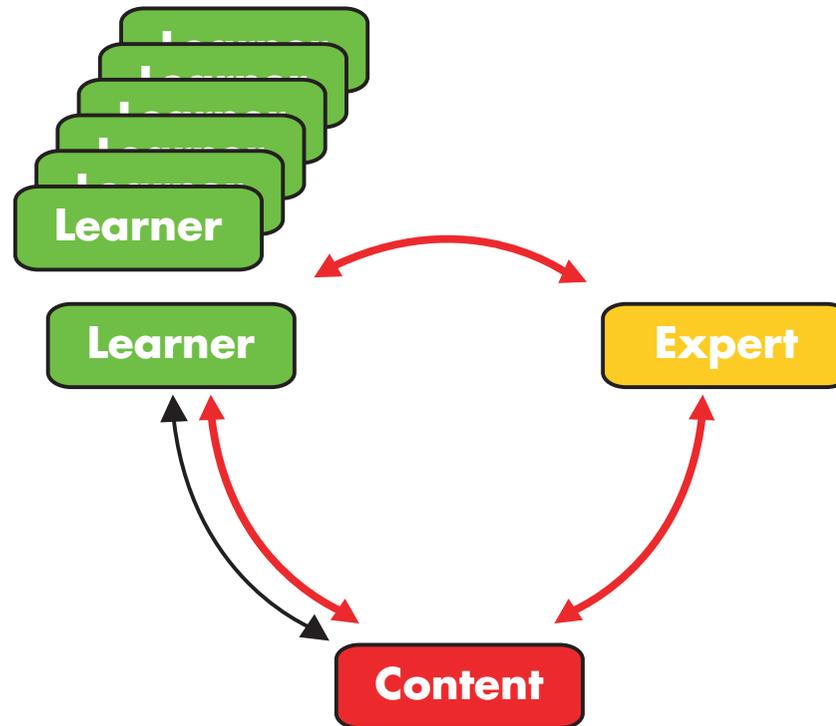
- Accessing multidisciplinary expertise as needed

Future Directions



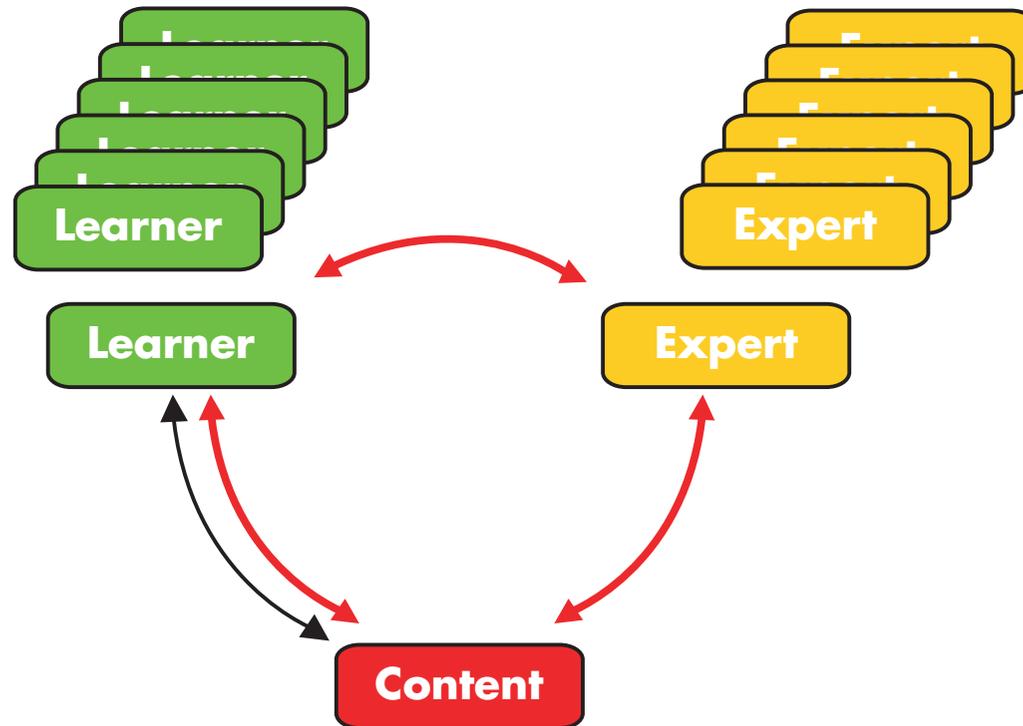
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Future Directions



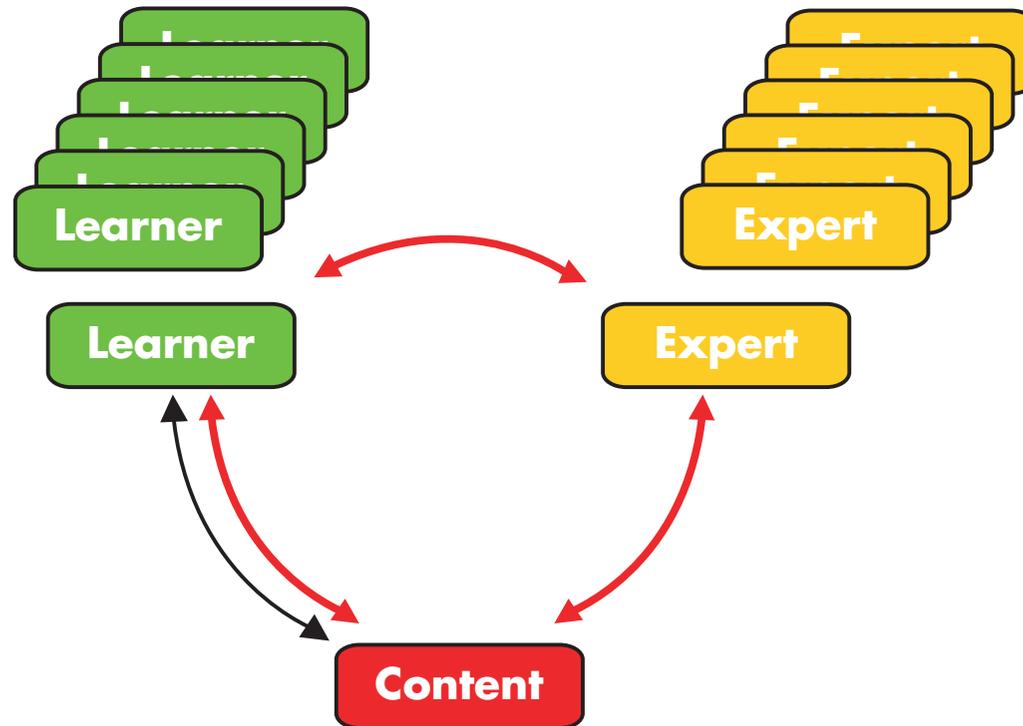
- Working in local and distributed teams

Future Directions



- Learning and training integrated into the work environment

Future Directions



- Simulations and virtual environments replicating, and merging with, the real environment

Participants

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Min Suk Chung



<http://havnet.stanford.edu>

Thanks for your attention!

